1984-12

An analysis of the economic impact of the AN/APS-134 FLAR retrofit on Coast Guard HC-130 aircraft

Dunn, Robert Earl

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/19133

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ANALYSIS OF THE
ECONOMIC IMPACT OF THE AN/APS-134 FLAR
RETROFIT ON COAST GUARD HC-130 AIRCRAFT

by

Robert Earl Dunn

December 1984

Thesis Advisor Paul M. Carrick

Approved for public release; distribution unlimited.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Analysis of the Economic Impact of the AN/APS-134 FLAR Retrofit on Coast Guard HC-130 Aircraft		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis December 1984
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert Earl Dunn		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE December 1984
		13. NUMBER OF PAGES 102
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Coast Guard FLAR, AN/APS-134, HC-130 Aircraft

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Concern over the growing drug smuggling problem and improved national defense capability are manifest in the need for a new forward looking airborne radar (FLAR) for Coast Guard HC-130 aircraft, with a capability of detecting a target of 1 square meter radar cross section. This thesis reexamines the analysis that selected the AN/APS-134 FLAR over other contenders based on mission need, radar performance and life cycle cost criteria.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This thesis presents a better understanding of the resulting HC-130 force structure based on the impact of FLAR technology.

Approved for public release; distribution unlimited.

An Analysis of the Economic Impact of the AN/APS-134 FLAR Retrofit on Coast Guard HC-130 Aircraft

by

Robert Earl Dunn
Lieutenant, United States Coast Guard
B.S., Kansas State University, 1972

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL

December 1984

ABSTRACT

Concern over the growing drug smuggling problem and improved national defense capability are manifest in the need for a new forward looking airborne radar (FLAR) for Coast Guard HC-130 aircraft, with a capability of detecting a target of 1 square meter radar cross section. This thesis reexamines the analysis that selected the AN/APS-134 FLAR over other contenders based on mission need, radar performance and life cycle cost criteria. This thesis presents a better understanding of the resulting HC-130 force structure based on the impact of FLAR technology.

TABLE OF CONTENTS

I. INTRODUCTION

A. THE PROBLEM

National defense and law and order are two major national issues that have been subject to considerable debate and have experienced increased national concern during the late 1970s and early 1980s. Following the Iranian hostage situation and other events in the Middle East, the capability of the United States to quickly project its military power to any spot on the globe and carry out sustained conventional warfare fell into some question. Likewise, concern has grown over the expanding illicit drug problem in the United States, its adverse impact on all facets of law and order and on the scope of efforts underway to combat it.

This increased concern over national security and drug abuse in the United States has been translated into tangible commitments through the reordering of national budget priorities. The reallocation of scarce resources during the first half of this decade was founded upon the belief that specific military preparedness and readiness capabilities, and drug interdiction goals could be reached through increased funding of the responsible agencies and their programs. It has been the responsibility of each agency to formulate the specific programs designed to meet articulated national goals in the most cost effective manner possible.

The United States Coast Guard has statutory responsibility as both the nation's primary maritime law enforcement agency and as one of this country's five armed services. While enforcement of laws and treaties and military preparedness are, but only two, of a myriad of humanitarian, regulatory and service missions performed by the Coast Guard, they do represent two of the largest and oldest traditional missions.

The constant challenges that face the Coast Guard in mission program management are, of course, parallel to those met by most government agencies once a national goal has been identified and a willingness to commit scarce resources has been made. First, a strategy and plan must be formulated to reach the goal. Second, the necessary organization needs to be created that will be able to realize the goal. This includes establishing the command and control structure, staffing all required billets with fully trained and motivated personnel and equipping the organization with the materials and equipment needed for full scale operations. Third, as organizational units conduct their operations in pursuit of the agencies assigned goals, the agency must evaluate results against tasking and adjust existing agency plans and assets while evaluating the possible benefits of alternate strategies, organization, hardware and technology.

Having long standing mission tasking in the areas of law enforcement and military preparedness, the Coast Guard has ongoing programs addressing each already in place. The impact of intensified national commitment to these missions has meant additional funding to reach higher levels of drug interdiction and increased levels of military capability and readiness primarily through the use of new or improved technology.

Typical of the various projects now underway to address upgraded tasking for illicit drug interdiction and improved military readiness, is the ongoing acquisition of the AN/APS-134 search radar for Coast Guard long range search (LRS) aircraft. This radar, when retrofit on the existing Coast Guard HC-130 fleet, is designed to greatly increase the aircraft's capability to locate surface targets in the maritime environment. In turn, other resources will then be able to board and seize the target, in case of illicit drug trafficking, or engage and defeat it, as in the anti-submarine military mission.

B. INTENT

Although a project to retrofit the Coast Guard HC-130 fleet with the AN/APS-134 search radar is already underway, the purpose of this thesis is to reevaluate the premise that the original AN/APS-59B search radar was no longer economically and technically adequate to meet new and

growing Coast Guard mission goals and objectives, within the economic context of life cycle cost effectiveness. The Development Plan for C-130 Aircraft Radar Retrofit, [Ref 1] prepared by the Naval Air Development Center, makes technical evaluations and comparisons of all logical replacement contenders and presents a limited life cycle cost analysis of the AN/APS-134 radar. However, no attempt has been made to provide the decision maker with a life cycle cost comparison based on a performance standard, or to address the impact of each alternative on force structure. This thesis will attempt to address the radar question from the economic perspective and provide the decision maker with the necessary information upon which to make a choice.

C. METHODOLOGY

The basic background material reviewed on Coast Guard programs and goals came from both special and periodic strategic planning documents. The Coast Guard Roles and Missions Study, [Ref 2] completed in 1982, provided an excellent strategic overview of how the Coast Guard expects to handle anticipated tasking over the next twenty-five years. The Operating Program Plans for each major mission (law enforcement, search and rescue, etc.) transforms strategic thinking into five year plans that are updated annually. All operating plan resource requests are integrated into major Coast Guard resource requirements

summaries. For aviation, they are published annually in a five year format titled Aviation Requirements.

Specific information on the Coast Guard decision to apply the new technology of the AN/APS-134 search radar against increased law enforcement and military readiness demands, came from three sources. First, all documentation in the Program Planning Office of the Coast Guard Aviation Branch was reviewed. Second, key personnel involved in the aviation planning, operations, maintenance and acquisition functions for Coast Guard aviation were interviewed. Third, all technical reports and evaluations on the different hardware options considered by the Coast Guard were reviewed.

Specific data on actual aircraft utilization for search and rescue and law enforcement flights flown during fiscal year 1983 were obtained from the Coast Guard search and rescue data base and Pacific Area law enforcement data base. The data was analyzed in order to validate and adjust the planning resource estimates presented in the Aviation Requirements FY87-91 (Draft Copy) [Ref 3] and mission operating program plans covering the same period [Ref 4, 5].

The economic analysis of which radar system will provide a cost effective solution to the Coast Guard's upgraded mission requirements, contrasts effectiveness and life cycle costs. Costs were estimated using the standard assumptions published by the Coast Guard Budget Division. The radar

effectiveness evaluation was based on background material for analyzing and comparing search radar capabilities. It was provided primarily by OEG Report 56: Search and Screening [Ref 6] and various other technical reference materials found at the Knox Library, Naval Postgraduate School.

II. BACKGROUND

A. HISTORICAL MISSION OVERVIEW

Originally founded in 1790 to deter maritime smuggling activities, the Revenue Cutter Service provides the historical roots for the present day Coast Guard. To its original role as a civil law enforcement agency came the role of military service, when, in 1796, Congress authorized the President to task the tiny Revenue-Marine (its popular name of the day) with the additional mission of "defending the Coast and repelling any hostility offered to U.S. vessels and commerce" [Ref 7].

To this unique blend of a military force and civil enforcement agency came a wide range of additional maritime related taskings, when over the following 150 years, the Steamboat Inspection Service, Lifesaving Service, Bureau of Navigation, Lighthouse Service, and Bureau of Marine Inspection and Navigation were all absorbed into one agency. The United States Coast Guard, as it was renamed in 1915, now had four major roles: military force; civil law enforcement agency; regulatory agency; and service agency.

The modern Coast Guard has divided the myriad of missions that comprise its four basic roles into thirteen operating programs:

1. Search and Rescue
2. Recreational Boating Safety

3. Enforcement of Laws and Treaties
4. Short Range Aids to Navigation
5. Radionavigation
6. Bridge Administration
7. Commercial Vessel Safety
8. Port and Environmental Safety/Marine Environmental Response
9. Waterways Management
10. Military Operations/Military /Preparedness/Reserve Training
11. Polar Ice Operations
12. Domestic Ice Operations
13. Marine Science Activities

The Coast Guard operates under the direction of the Secretary of Transportation except in time of declared war or as directed by the President, when control is transfered to the Secretary of Defense for augmentation of U.S. Naval Forces.

B. AVIATION SUPPORT

Coast Guard interest in the use of aircraft for search and patrol activities dates back to 1916 when the first few pilots and crews were trained based on Congressional authorization to build and equip a coastal network of Coast Guard air stations. But, appropriations to fund Coast Guard aviation were not made until 1926, following years of Coast Guard experimentation and a successful "Prohibition" anti-smuggling program off Massachusetts using borrowed Navy airplanes [Ref 8]. By 1940, the Coast Guard had 50 aircraft and a network of eleven air stations. During World War Two, Coast Guard search and rescue, and patrol expertise were enhanced by the addition of newer, front line aircraft.

Further, the Coast Guard served as the core for a newly established national Air-Sea Rescue Agency, monitored weather and tracked icebergs in the North Atlantic and flew many of the sea lane control/anti-submarine sorties along the Coast of the United States.

Currently, the Coast Guard operates a total of 171 fixed and rotary wing aircraft from 26 permanent air stations in support of all Coast Guard mission programs. Different aircraft types are procured to satisfy each of four distinct mission need categories. For rotary wing aircraft there are the Short Range Recovery (SRR) and Medium Range Recovery (MRR) mission categories, and for fixed wing aircraft there are the Medium Range Search (MRS) and Long Range Search (LRS) categories. These catagories are define in the Coast Guard <u>Aviation Requirements FY86-90</u> [Ref 9] planning document as:

1. An SRR helicopter would be required unless one of the following was exceeded during a mission.
   a. Total sortie flight time of 3.0 hours.
   b. Recovery of three persons from distress.
   c. Transportation of five passengers.
   d. Cargo sling capacity of 2,000 pounds.
   e. Radius of action of 150 nautical miles.

2. If any one of the above is expected to be exceeded during a mission, the MRR helicopter would be required.

3. An MRS fixed wing aircraft would be required unless one of the following was exceeded during a mission.
   a. Total sortie time of four hours.

b. Transportation of three passengers.
c. Total radius of action of 750 miles at 30,000 feet.
d. Total radius of action of 370 miles at 2,000 feet.
e. Transportation of any significant size or weight of cargo.

4. If any one of the above is expected to be exceeded during a mission, the LRS would be required.

Twenty-two Lockheed HC-130 Hercules aircraft are currently being used to fill the LRS role. The HC-130 is a variant of the tough and versatile C-130 turboprop, tactical airlift aircraft, first developed for the U.S. Air Force in 1955. The Hercules first entered the Coast Guard LRS fleet in 1960 and is capable of carrying up to 92 passengers or vehicle sized cargos, at a cruise speed of 300 knots at an altitude up to 33,000 feet (see Figure 1). Long range cruise patrol speed at 1,000 feet varies between 200 and 234 knots, based on gross weight. Patrol sortie endurance can be extended from 9 to 12 hours using reduced engine operations (the HC-130 can patrol using two or three engines at lighter gross weights when in favorable weather conditions) and depending on the distance flown at high altitude to and from the patrol area.

Coast Guard LRS assets are located at five permanent air stations: Barbers Point, Hawaii; Kodiak, Alaska; Sacramento, California; Clearwater, Florida; and Elizabeth City, North Carolina. Guantanamo Bay, Cuba is used as a

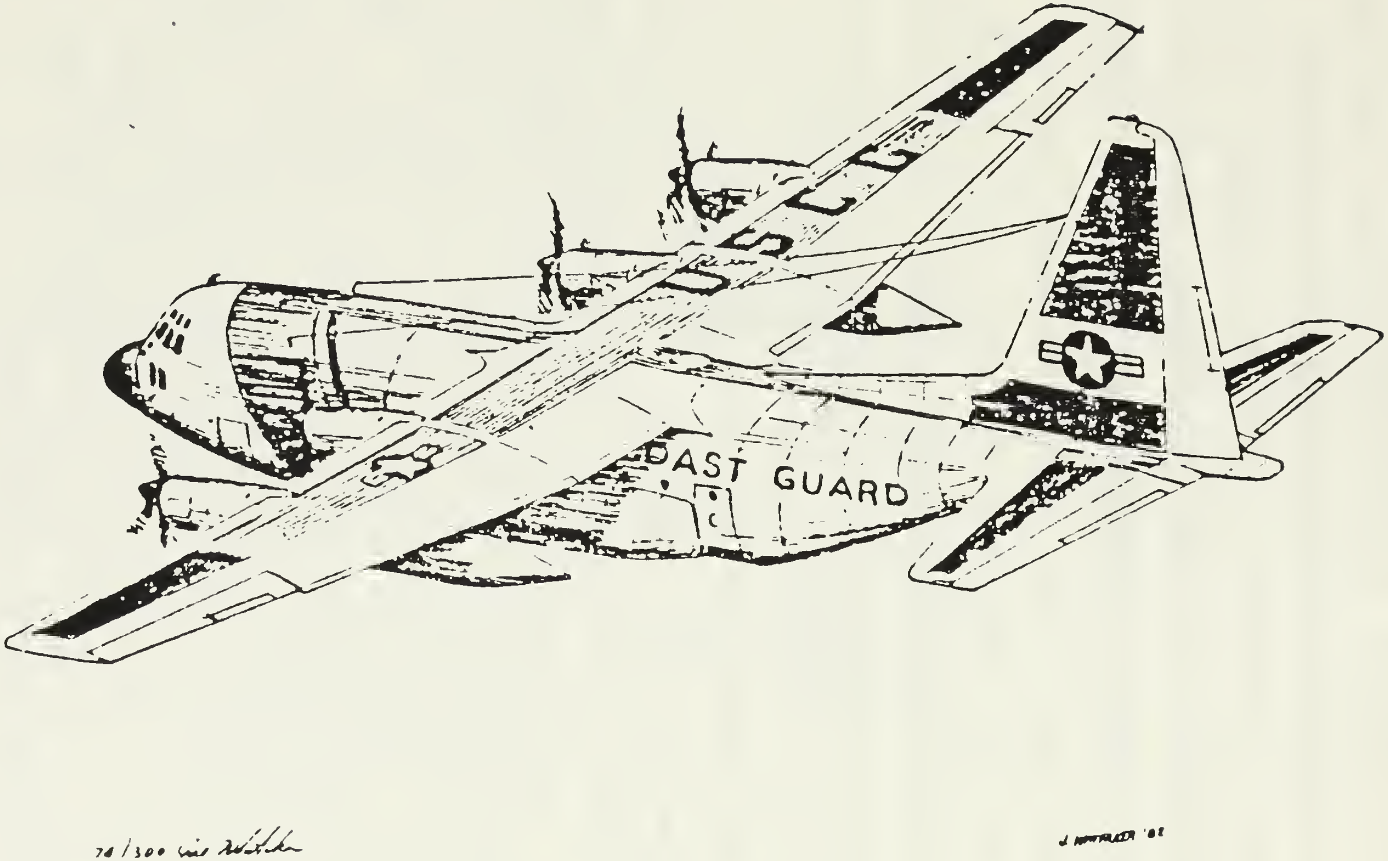


Figure 1. Coast Guard HC-130 LRS Aircraft

forward deployment base on a constant basis, using LRS assets from Clearwater and Elizabeth City.

C. MISSION ANALYSIS

The greatest impact on the design and composition of Coast Guard aviation is made by the physical limitations imposed by mission workload demands, scheduled and unscheduled maintenance, manpower availability and budgetary restrictions. Maintenance and manpower demands are tied together by the fact that Coast Guard aircraft are piloted by the air station's officers and are crewed by the station's maintenance specialists. This "fix'em-fly'em" concept is economical but can impose limitations during peak periods of aircraft utilization.

The flight hour is the basic unit used for planning, programming and budgeting. The historically proven utilization rate used for LRS planning is 800 hours per year. This factor is applied to each operational HC-130 aircraft assigned to a field unit. It should be noted that of the total FY84 fleet of 22 HC-130s, only 18 were considered as operationally assigned to field units. The remaining aircraft are spares and allow for fleet rotation to overhaul or modification facilities. A 25% overload factor is considered before an additional airframe is assigned. Table 1 lists the standard utilization rates used to assign aircraft to field units.

Although all Coast Guard Mission programs can receive LRS support, most only require occasional logistics sorties. The Search and Rescue, Law Enforcement, Military Operations and Polar/Domestic Ice Operations missions are all programs that can make the most frequent and extensive use of the HC-130 as a search platform. Appendix A provides a general overview of projected flight hour needs by operational program, as compiled in Aviation Requests FY87-91 (draft copy).

Table 1: Standard LRS utilization assignment rates

Projected LRS Hours	Airframes
0-1800	2
1801-2600	3
2601-3400	4
3401-4200	5
4201-5000	6

1. Search and Rescue (SAR)

The Search and Rescue program is the foundation upon which Coast Guard aviation is built. While each Coast Guard facility type (i.e. aircraft, cutters, boats) is by definition and design a multi-mission platform, each facility type is tied to a primary program sponsor who is responsible for its basic budget support. For aviation, the Search and Rescue program is the facility sponsor. Accordingly, the Search and Rescue program has immense influence on the quantity, composition and deployment of aviation resources.

The Search and Rescue program has established a requirement that each of the five LRS equipped air stations maintains one "Bravo Zero" (B-0) HC-130 aircraft. A B-0 LRS must be capable of being airborne within 30 minutes of first notification, or diverted from the local flying area with a fully qualified SAR crew and ample fuel, if already airborne. Accordingly, each air station maintains one "ready" crew and aircraft on alert at all times [Ref 10].

The impact of B-0 tasking on the standard utilization rate method of making LRS aircraft assignments is two fold. First, based on a historically proven "not operationally ready" (NOR) rate of 29% per HC-130 due to maintenance, a minimum of three HC-130 aircraft must be assigned to each LRS station. This must be done to insure that at least one aircraft is available 98% of the time. As presented in Table 2, Aviation Requirements FY87-91 [Ref 11] has computed the probabilities of having at least one aircraft available based on a 29% NOR rate.

Table 2: Probability of at Least One LRS Available

Number of LRS	NOR Rate
1	.710
2	.916
3	.976

Second, additional manning is made to meet the demands that a 24 hour a day, alert requirement creates. This advantage

diminishes as additional LRS airframes are assigned, since additional aircraft bring only the minimum number of pilots and crews needed to operate and maintain them.

The Search and Rescue program is projected to require 6,459 hours for 25% of total FY87 flight hours and 5,880 hours for 20% of FY91 flight hours (see Appendix A). There are two, broad LRS SAR case scenarios that account for these flight hours: The immediate response case and the extended search case.

The immediate response sortie typically scrambles the B-0 LRS in response to a critical situation such as a vessel taking on water, on fire, lost, capsized, disabled, etc. In this case, the vessel in distress usually initiates the call for help. The job of the LRS in this situation is to initially locate the vessel and attempt to stabilize the situation by air dropping dewatering pumps, life rafts or other critical supplies, as necessary. The LRS then acts as the On Scene Commander (OSC) and coordinates the rescue or other assistance provided by Coast Guard helicopters and surface units, or other vessels. The search necessary on these sorties is usually limited to locating the distress vessel or survivors in a highly localized area using radio direction finding equipment, radar and visual signal devices.

The extended search is more extensive and is conducted by one or more aircraft when the exact location of

a distress is not known. Typically, these sorties are in response to overdue vessels or when an immediate response flight is unable to locate a vessel in distress or all its survivors. These missions involve extensive preflight planning and rely primarily on the LRS crew as visual observers to locate small targets like wreckage, rafts or people in the water.

2. Enforcement of Laws and Treaties (ELT)

A growing program, LRS sorties have been flown in support of three main enforcement efforts over the past few years: narcotics, fisheries, and illegal aliens. Appendix A projects that 10,117 hours for 39% of FY87 LRS hours and 13,758 hours for 47% of FY91 LRS hours will be flown for the ELT program.

Interdiction of narcotics smuggling vessels represents the largest investment of Coast Guard LEF effort. The Enforcement of Laws and Treaties Operating Program Plan FY87-91 [Ref 12] summarizes the scope of the narcotic problem as:

> Ten to fifteen thousand meteric tons of marijuana are supplied to the U.S. market from foreign sources annually. Of this, approximately 6,000-9,000 tons of marijuana are shipped by sea. Columbia accounts for approximately 75% of all marijuana shipped to the U.S. Given the enormousprofits to be made from smuggling marijuana and other drugs into the United States a large rate of seizure is necessary in order to have a deterrent effect. A 70% level of interdiction may force smugglers to use other techniques such as increased aircraft or overland

transportation.

Coast Guard interdiction rates for the early 1980s against seaborne smuggling is estimated at between 15-20%.

The Caribbean and off Baja, Mexico are the two primary areas that anti-smuggling efforts are concentrated. Due to the geography of Columbia, most illicit narcotics transit the Caribbean to the Southeastern United States. The islands and corresponding passes (Windward, Yucatan, Mona, Anegada, etc.) allow the concentration of friendly forces at "choke points". In the Pacific, geography has provided no advantages. The West Coast of Columbia is mountainous and costs the smuggler more to ship from, but there are no natural barriers that create choke points.

In the Caribbean, LRS aircraft directly support Coast Guard cutters underway in the passes. The aircraft serve as the eyes of the fleet in locating suspect vessels, and the cutters provide the boarding capability. Typically, barrier patrols are flown.

In the Pacific, LRS aircraft frequently fly without dedicated vessel support due to the vast area through which a smuggler can approach the United States. LRS sorties usually have little intelligence data to work from and are more random in nature.

Smuggling vessels fall into three broad catagories. The primary target is the "mothership" and serves as a major

transporter of narcotics from Columbia to U.S. Coastal waters. The "mothership" is 60-300 feet in length and is typically a large fishing vessel or small coastal freighter. The "contact" boat is a small boat 16-30 feet in length that transports the contraband from the "mothership" to shore. These vessels are recreational vessels or small fishing vessels. Finally, some large sailing and fishing vessels, from 45-90 feet in length, make the entire trip from South America to the United States. These vessels tend to stay closer to the coast (100 miles) and unload in secluded areas at night.

Fisheries law enforcement takes place within the 200 mile Fisheries Conservation Management Areas (FCMA) adjacent to the continental United States, Alaska, Hawaii and the Pacific Island Territories of the United States. Within the FCMA, all foreign fishing vessels must be licensed for fishing by the United States, must abide by U.S. regulations, and submit to inspection. Further, limited regulation is conducted for U.S. vessels involved in critical fisheries such as salmon.

The LRS role in fisheries enforcement is to patrol FCMA fishing grounds and locate vessels in violation of season and position regulations, and to locate vessels for periodic boarding by Coast Guard and National Marine Fisheries boarding teams. The mission profile for fisheries' patrols is to follow the 100 fathom curve, where

most fishing activity takes place, and to cover closed or restricted areas.

The illegal alien problem is connected primarily to Haiti and is small relative to the drug interdiction and fisheries missions. Here, the approaches to Florida from Haiti are patrolled to interdict illegal aliens attempting to enter the Uniter States in small, usually unsafe, wooden vessels. This mission is done in conjunction with Caribbean drug interdiction operations.

It should be noted that the expansion of the drug interdiction mission is the largest driving force in creating the LRS shortage, as depicted in Appendix A, Summary of Aircraft Requirements FY87-91.

3. Military Operations

During times of National Emergencies, Coast Guard LRS assets are programmed to deploy with Coast Guard medium endurance cutters to provide SAR coverage for lines of communication (sea laws and airways) that lead into combat theaters of operation. Additionally, LRS aircraft will support U.S. forces in the protection of U.S. Maritime Defense Zones that surround the nation. In this capacity, HC-130 aircraft will conduct patrols to locate enemy forces capable of interdicting friendly vessels and disrupting sea lines of communication. It is expected that submarines will be the primary target. Their location will be fixed by detecting periscopes or snorkels.

In peacetime, no dedicated LRS patrols or training flights are flown for the Military Operations program. Only medium and high endurance Coast Guard Cutters receive annual training and must qualify in Naval military operations. The lack of an LRS sensor, capable of locating a submerged submarine's periscope or snorkel, and the lack of available LRS resource flight hours, leave the program without support.

4. Ice Operations

Since the formation of the International Ice Patrol in 1914, following the Titanic disaster in 1912, the Coast Guard has provided the bulk of the world's iceberg detection and tracking capability. Currently, specially equipped HC-130 aircraft patrol the North Atlantic each summer. These special LRS aircraft are equipped with side looking airborne radar (SLAR) used to locate the ice flows, which are then marked with an electronic transmission device that is tracked by satellite.

D. SEARCH THEORY

Before beginning a discussion of the events surrounding the Coast Guard decision to refit the HC-130, LRS fleet with the AN/APS-134 search radar, a quick review of the basic concepts of search theory is appropriate.

Binary Detection Theory provides the basis for most detection modeling. In this theory, an obervation is made

of a specific region over a known time period. This region can be referred to as an "observation cell". Within an observation cell, at least one target will be present (defined as event T_1), or no targets will be present (defined as event T_0). In addition, an observer must either determine, from the observation data available, that at least one target is present (defined as event D_1), or no targets are present (defined as event D_0). These four events are best understood using a Venn diagram (see Figure 2) to describe the possible outcomes for a given observation cell [Ref 13].

T_1 and D_1 (correct call)	T_1 and D_0 (missed detection)
T_0 and D_1 (false alarm)	T_0 and D_0 (correct call)

T_1	At least one target actually present
T_0	No targets actually present
D_1	Observer determines at least one target present
D_0	Observer determines no targets present

Figure 2. Binary Detection Theory Venn Diagram

The "probability of detection" (P_d) is the conditional probability that the observer determines that at least one

target is present in the observation cell, given that at least one target is actually present in the cell.

$$P_d = P(D_1/T_1) \qquad (1)$$

The "probability of false alarm" (P_f) is the conditional probability that the observer determines that at least one target is present in the observation cell, given that no targets are actually present in the cell.

$$P_f = P(D_1/T_\emptyset) \qquad (2)$$

The observer's willingness to react to the observation input data obtained from each observation cell determines the trade off between false alarms and detections. If an observer places a high cost on missed detections, and thus a high value on the probability of detection, he will tend to be sensitive to all observation data and, consequently, he will be inclined to experience a high false alarm rate. Conversely, if the observer places a high cost on the number of false alarms, he will tend to establish more stringent evaluation criteria for incoming observation data, and consequently will be inclinded to increase the number of missed detections.

A search unit has some limit to the range capability of its sensor, whether it is the eyesight of a visual observer

or the maximum range of a radar. This distance is known as the "maximum detection range" (see Figure 3). Since an aircraft can sweep its radar back and forth to search both sides of an aircraft's flight path, or a visual observer can be posted to search each side, the maximum detection range is doubled to equal the "maximum detection distance" (see Figure 3).

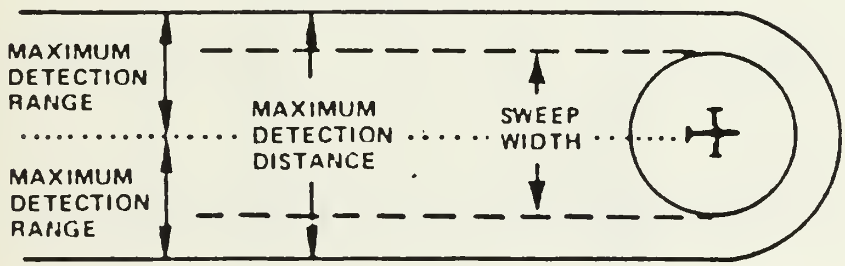


Figure 3. Pictorial Presentation of a Search Sweep

Clearly, any visual observer should understand that his ability to easily see and identify a target is a function of his distance from the target in question. When an aircraft, on a constant course, encounters a surface target (ship, raft, etc.) the very high speed of the aircraft, relative to the surface target's speed, creates a "straight line encounter" [Ref 14]. For this kind of encounter the relative motion of an aircraft and a target are best depicted as in Figure 4, where the aircraft is at the origin and the Y axis is aligned with the aircraft's flight path.

In the reference frame of figure 4, the target would appear to move parallel to the Y axis at the aircraft's speed and at some "lateral range" X_1. Lateral range is the horizontal range at the closest point of approach (CPA). CPA is the target's horizontal range when the target intersects the X axis.

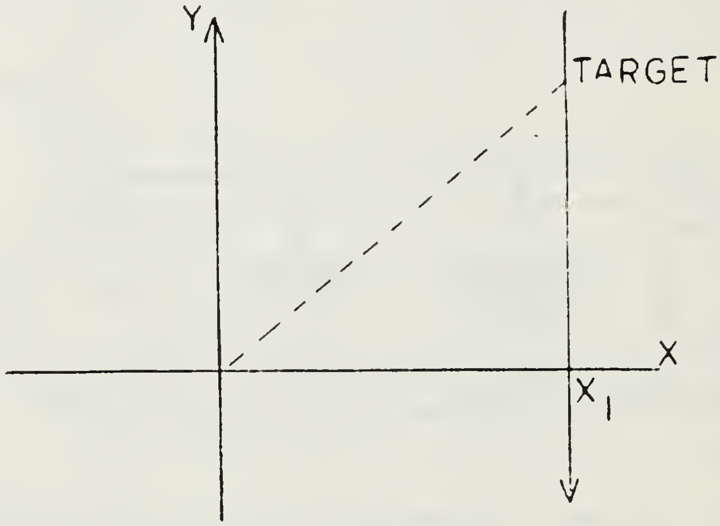


Figure 4. Straight Line Encounter

For a straight line encounter the probablilty of detection can be expressed as a function of the lateral range X. In symbols:

$$P_d = P(x) \qquad (3)$$

Figure 5 depicts a number of different lateral range curves to demonstrate how the capability of different systems and models vary.

The definite range law (Figure 5a) defines a simple yes/no sensor that is assumed to always detect its target inside a given range, and never outside that maximum range.

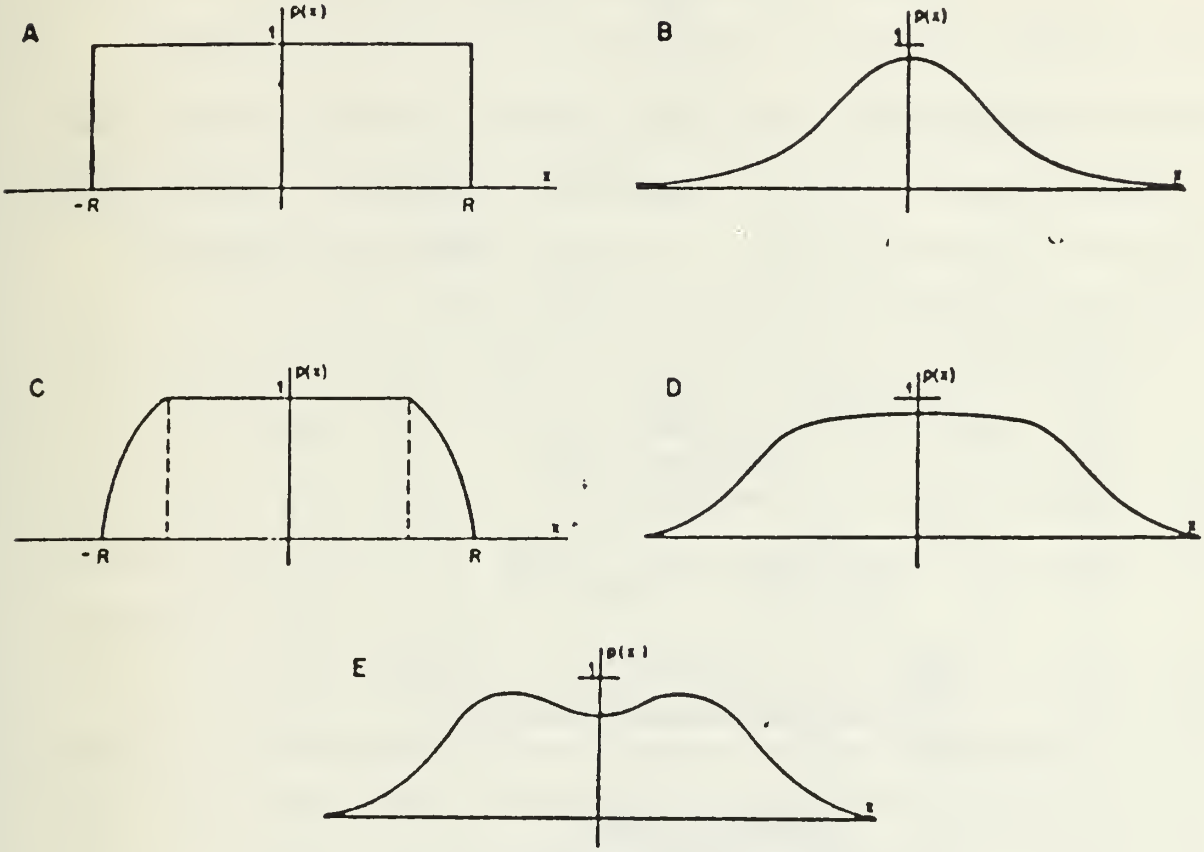


Figure 5. Sample Lateral Range Curves

The inverse cube law (Figure 5b) serves as the basis for aircraft visual searches. Figures 5c and 5d represent modifications to the definite range law and inverse cube law, respectively, and Figure 5e is typical for a radar to include a low range probability of detection dip caused by sea clutter.

The mathematical area under the lateral range curve, represents the effective search (sweep) width W. That is,

$$W = \int_{-\infty}^{+\infty} P(x)\, dx \qquad (4)$$

Figure 6a represents a lateral range curve for an ideal case in which target lateral ranges are uniformly distributed across the detection range. In this case, the area under

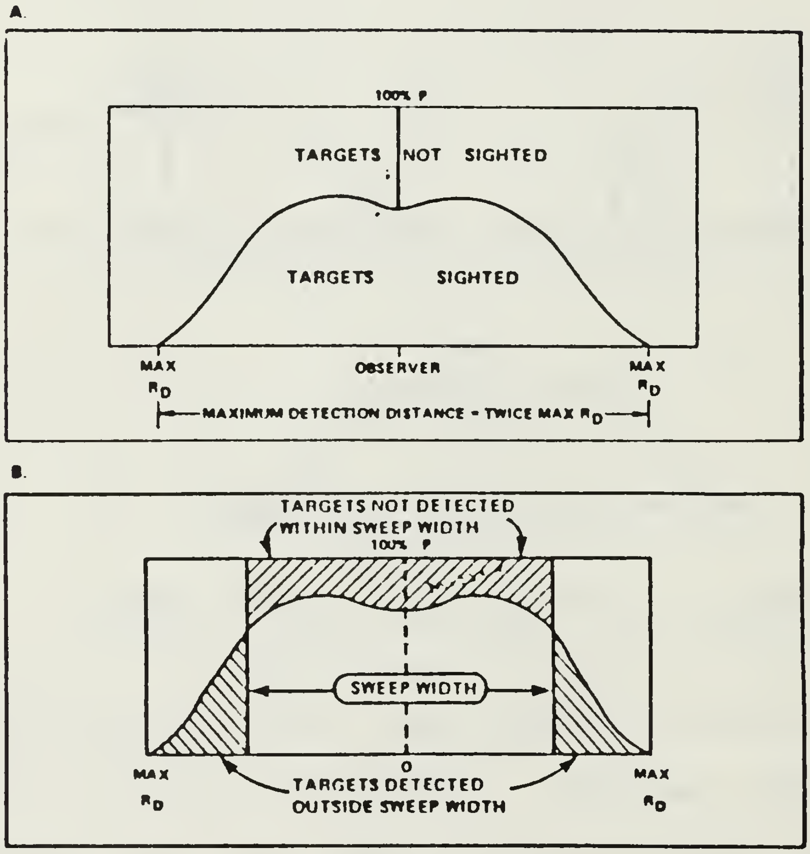


Figure 6. Graphic Presentation of Sweep Width

the curve is proportional to the number of targets detected and the area above the curve is proportional to the number

of targets not detected. Figure 6b shows that sweep width could be defined as twice the distance, such that the number of targets missed within that distance is equal to the number of targets detected beyond that distance.

It should be understood that each detection system will have its own unique lateral range curve and its own unique sweep width for a given target.

1. Search Patterns

The Coast Guard uses a variety of search patterns (see Appendix B) to conduct its radar and visual searches. With the exception of the sector search, they are all equivalent to parallel sweeps over an ocean where the probability that any given area contains the target is considered equal.

Search by parallel sweeps simply takes an individual search sweep, as depicted in Figure 3, and combines it with other parallel sweeps to cover an area. Normally, these parallel sweeps are accomplished by a single unit conducting a series of parallel sweeps of equal length. The distance between the sweep center lines (the searcher's normal flight path) is defined as S, the "track spacing" (see Figure 7).

2. Visual Search

Visual search has long been the Coast Guard mainstay for locating small targets such as rafts, wreakage, people in the water and vessels under 50 feet. The detection model used by the Coast Guard for visual search was developed from

the basic inverse cube law model, a simplified model of visual detection. For a parallel sweep search, the model

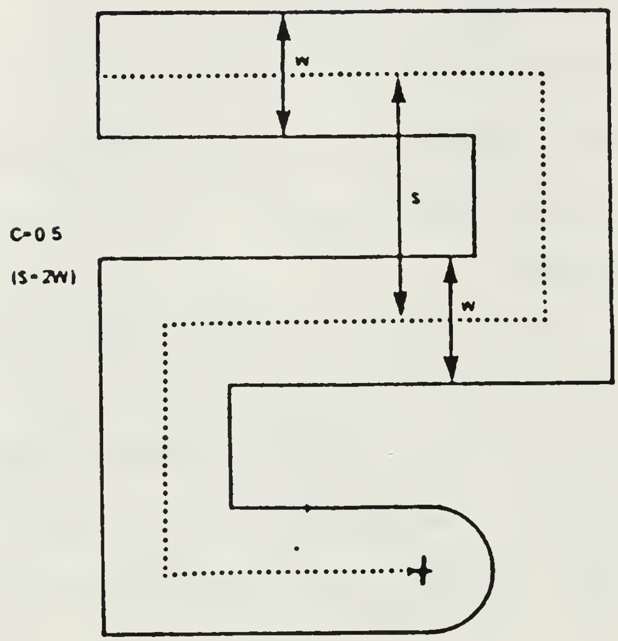


Figure 7. Track Spacing and Coverage Factor

gives detection probabilities that depend on coverage factor (C). Coverage factor (see figure 7) is defined by:

$$C = \frac{W}{S} \tag{5}$$

Using coverage factor, probability of detection is determined by using the graphs in figure 9. Multiple curves are provided to account for the probabilites created by researching an area. A set of tables (figure 8), based on

Sweep Width (W) For Visual Search

(W Given In Nautical Miles)

Altitude (100 ft)	Liferafts 0	Liferafts 5	Liferafts 10	Liferafts 20	Boats (less than 30') 0	Boats (less than 30') 5	Boats (less than 30') 10	Boats (less than 30') 20	Boats (less than 30') 30	Boats (30-60') 0	Boats (30-60') 5	Boats (30-60') 10	Boats (30-60') 20	Boats (30-60') 30
1	0.5	0.5	0.5	-	0.5	0.5	0.5	-	-	9.5	0.5	0.5	-	-
3	1.0	1.2	1.2	1.0	2.5	2.4	2.3	1.8	0.4	3.5	3.0	2.7	1.8	0.4
5	1.0	1.6	1.6	2.7	2.7	2.7	2.7	3.2	3.3	4.2	4.2	4.2	4.2	3.3
10	1.8	1.8	2.1	3.8	3.9	4.0	4.2	4.5	5.8	6.5	6.2	6.2	6.2	6.5
15	1.9	3.9	2.6	3.8	5.2	5.3	5.5	8.7	7.0	8.5	8.5	8.4	8.4	8.3
20	2.0	2.1	2.8	3.6	5.3	5.6	6.2	6.8	7.1	8.6	8.8	9.0	9.1	8.9
30	2.2	2.3	2.9	3.8	5.5	6.2	7.0	7.0	7.1	8.7	9.5	10.4	10.1	8.7
40	2.2	2.4	2.9	3.6	5.6	8.3	7.1	7.1	7.2	8.9	10.0	11.0	10.8	10.3
50	2.2	2.4	3.0	3.8	5.7	6.6	7.2	7.2	7.3	8.0	10.0	11.9	11.3	10.7

Altitude (100 ft)	Boats (60-90') 0	Boats (60-90') 5	Boats (60-90') 10	Boats (60-90') 20	Boats (60-90') 30	Small Ships (300-1000 Gross Tons) 0	Small Ships 5	Small Ships 10	Small Ships 20	Small Ships 30
1	1.0	0.5	0.5	-	-	1.0	1.0	1.0	-	-
3	3.9	3.4	3.2	1.8	0.4	4.2	3.8	3.2	1.8	0.4
5	5.0	5.0	4.9	4.7	3.3	7.1	8.7	8.2	4.9	3.3
10	8.0	8.0	7.8	7.7	7.2	11.8	10.0	9.8	8.6	7.2
15	11.0	9.9	9.6	9.1	8.5	13.4	12.7	12.0	10.5	9.1
20	12.0	11.0	10.6	10.0	8.3	15.8	14.3	13.5	11.8	10.4
30	12.5	12.5	12.1	11.3	10.5	17.0	18.5	15.7	13.9	12.2
40	13.0	13.0	11.2	12.2	11.3	17.0	17.0	17.2	15.3	13.5
50	13.5	13.5	14.0	13.0	11.9	20.0	18.3	18.6	18.4	14.5

Altitude (100 ft)	Medium Ships (1000-10 000 Gross Tons) 0	Medium Ships 5	Medium Ships 10	Medium Ships 20	Medium Ships 30	Large Ships (Over 10 000 Gross Tons) 0	Large Ships 5	Large Ships 10	Large Ships 20	Large Ships 30
1	1.0	1.0	1.0	-	-	1.0	1.0	1.0	-	-
3	4.6	4.0	3.3	1.8	0.4	4.7	4.0	3.3	1.8	2.4
5	8.0	7.0	6.2	4.9	3.3	8.8	7.0	4.8	4.8	1.3
10	11.0	10.6	10.2	9.0	7.2	11.0	10.6	10.2	9.1	7.2
15	14.0	13.7	13.3	11.4	9.4	14.0	13.8	11.7	11.6	9.5
20	15.0	15.0	15.1	11.0	10.8	15.0	15.0	15.8	13.3	11.1
30	17.0	17.0	17.0	15.4	13.1	17.0	17.0	17.0	15.8	11.4
40	17.0	17.0	18.0	17.1	14.7	17.0	17.0	17.0	17.5	15.3
50	20.8	21.0	20.8	18.3	15.9	20.0	21.0	21.8	14.9	18.5

WHITECAP CORRECTION FACTOR (f_w)

Wind (kts)	0	10	15	20	25	30	40	50	60
Rafts	0.8	1.0	0.9	0.7	0.5	0.2	0.1	-	-
Boats	0.8	1.0	1.1	1.0	0.9	0.7	0.2	-	-
Ships	1.1	1.0	1.0	0.9	0.8	0.7	0.5	0.2	-
Dye Marker	0.9	1.0	1.0	0.9	0.8	0.4	0.2	-	-
Smoke	0.8	1.0	0.8	0.6	0.4	0.2	0.1	-	-

LIGHTING CORRECTION FACTOR (f_l)

Percent Cloud Cover	0	10	20	30	40	50	60	70	80	90	100
Cloud Cover Factor	1.1	1.1	1.1	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7

$$W = (W_u)(f_w)(f_l)$$

Figure 8. Sweep Width Computational Tables

experimental data gained through field testing, have been developed to easily determine sweep width. The tables are based on the following operational factors: Aircraft altitude, target size, meterological conditions and sea conditions.

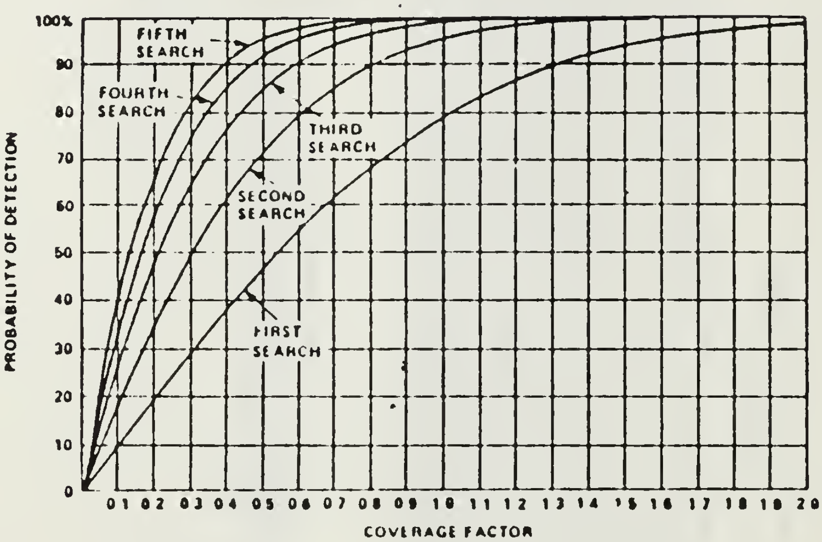


Figure 9. Probability of Detection

3. Radar Search

The principle of radar is to transmit an electromagnetic signal and then detect any signal reflected back off a target. If a target is not present in an observation cell, the input to a radar corresponding to the observation cell equals only noise (non-target reflected or generated signal). If a target is present, the input equals noise plus signal. The reflected signal received and the random "noise" are converted into a voltage that produces a "blip" on a cathode ray tube (scope) if the voltage exceeds an established threshold.

A practical example of binary detection theory is seen in Figure 10. There, the relative frequency distributions are given for both noise voltage (no target present) and noise plus signal voltage (target present). Using a voltage threshold of V_t, a region of false alarms is created at the upper end of the noise distribution where observations exceed V_t. Likewise, an area of missed detections is created at the lower end of the noise plus signal distribution for observations less than V_t.

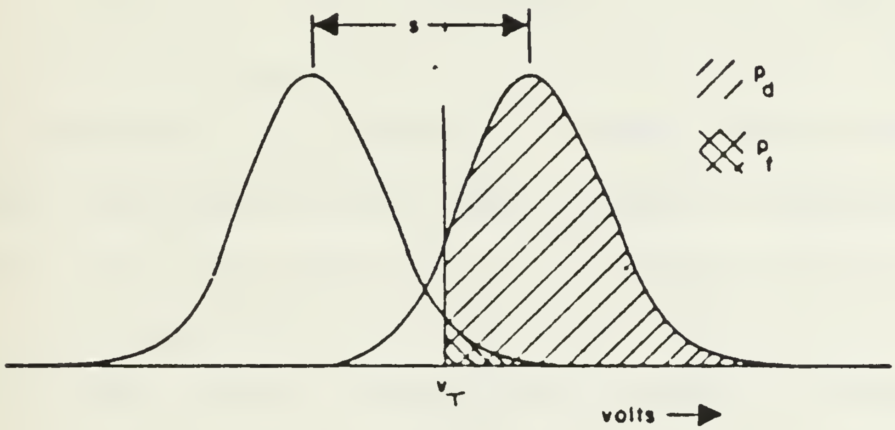


Figure 10. Decision Voltage Distributions

Although different forward looking radars (FLAR) are designed for such specialized purposes as weather avoidance, surface mapping and maritime search, all radar return signals are subject to the same physical realities that determine basic radar capability. The basic radar equation serves to outline some important factors that determine radar capability.

Signal power received (S) is a function of: Power transmitted (P); antenna gain (G); signal wave length (λ); radar cross section of the target (σ); range of the target (R) and system losses (L). It is important to note that the basic radar equation ignores the effect of important environmental factors that can cause significant degradation in system performance. These include sea conditions and propagation conditions such as ducting and lobing.

$$S = \frac{P\ (G\lambda)^2\,\sigma}{(4\pi)^3\ R^4} \tag{6}$$

The maximum range of a radar is determined by minimum acceptable signal-to-noise ratio $(S/N)_{MIN}$. For an unjammed radar environment, this ratio is:

$$(S/N)_{MIN} = S_{MIN}/N \tag{7}$$

The noise power (N) is a function of: the Boltzman's constant (K); absolute temperature (T); noise figure of the receiver (F_N); and receiver band width (B_R). The relationship $N = kT(F_N)(B_R)$.

Using Equation 6, the simple radar equation, and Equation 7 gives:

$$R = \left[\frac{P\,(G\lambda)^2}{(4\pi)^3\,(k)\,(T)\,(F_N)\,(B_R)\,(S_{MIN})\,(L)} \right]^{\frac{1}{4}} \sigma^{\frac{1}{4}} \quad (8)$$

By using the signal power S_{MIN} corresponding to the voltage Vt, it would be possible to use Equation 8 to determine the range corresponding to a given probability of detection and probability of false alarm. Such values could, in turn, be used to estimate a lateral range curve by using the technique described in Reference 15. However, a more desireable way to determine a lateral range curve would be by using operational data, rather than the method outlined above [Ref 15].

To determine the overall probability of detection for a radar parallel sweep search, given a lateral range curve from which a sweep width can be determined, the random search model described by Equation 9 can be used.

$$P(S) = 1 - e^{-W/S} \quad (9)$$

The random search model yeilds a more conservative, and some argue, a more realistic result than does the model that is based on precise navigation and the inverse cube law that the Coast Guard uses. Figure 11 graphically depicts how

probability of detection calculated for a parallel sweep search varies between the inverse cube model and the random search model.

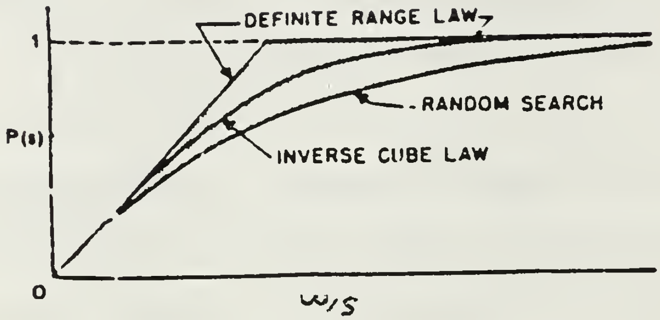


Figure 11. Probability of Detection for Parallel Sweep

The Coast Guard provides aircrews with no accurate way to compute measures of radar search effectiveness. There is no technical data readily available on FLAR systems and no charts or nomographs have been produced for field use. The only guidance provided is in the National Search and Rescue Manual which states [Ref 17] that "Sweep width tables for various electronic searches are not as readily available as visual sweep width tables. Yet a sweep width should be developed for all types of searches in order to obtain the probability of detection and track spacing." To determine the parameters for a radar search, it directs the use of the "Electronic Locator Transmitter" sweep width guidelines of [Ref 18]:

1. When minimum detection range is known:
   W = (1.7) (minimum detection range)
2. When average detection range is known:
   W = (1.5) (average detection range)
3. When maximum detection range is known:
   W = (1.0) (maximum detection range)
4. When no detection range is known:
   W = (0.5) (range to the horizon)

The few aircrews that attempt to compute FLAR probability of detection using the SAR Manual guidance, inevitably use the visual coverage factor/probability of detection conversion graph (Figure 9), as it is the only one provided. Since this graph is based on the inverse cube law, a simplified theoretical visual search model, and perfect navigation, the results could be erroneous.

E. LIFE CYCLE COST

The life cycle cost of a system is comprised of all costs associated with a system over its entire life span. A typical breakdown structure for a system will divide costs into the three major subcategories of: Research development, test and evaluation costs; production costs; and operations and maintainance support costs.

F. AN/APS-134 BUY DECISION

The LRS fleet had grown from the original 12 HC-130s purchased in the early 1960s to a total inventory of 25 by January 1978. The additional aircraft had been purchased in

small buys (1, 3, 5 and 4 plane purchases) every 3 to 5 years to meet the need of a growing LRS work load. By 1978, it was clear that LRS basic annual utilization rates would be exceeded by most of the five LRS air stations and that the original 12 airframes would be worn out by the end of that decade.

The LRS resource plan called for the renewal of the LRS fleet through the purchase of replacement HC-130 airframes. The government would supply Lockheed Georgia with the engines and high cost electronic equipment; these items were to be removed from the retiring HC-130s. The expense of this renewal of the LRS resource base made LRS fleet expansion in the early 1980s out of the question.

Realizing the constraints on LRS fleet expansion and growing LRS mission tasking, Coast Guard aviation planners looked at the HC-130s FLAR as a way to increase mission efficiency and effectiveness. Since the rapidly growing ELT mission used the radar as its primary search sensor, it was natural to pursue this avenue.

The LRS fleet was equipped with the AN/APN-59B radar as part of a "Navy type-Navy owned" (NTNO) agreement. Under this agreement, the Navy had purchased the radars and paid for all replacement parts. The APN-59B was originally designed as a navigation/weather radar and was built using vacuum tube technology. Accordingly, the APN-59B uses a lower power and pulse ratio than does a FLAR designed

specifically for maritime search and surveillance. Reliability of the APN-59B was never high, but due to its age, mean time between failures (MTBF) had fallen to about 50 hours.

Coast Guard budgets that included funding for a new FLAR were submitted in FY79, 80 and 81, but it was not until FY82 that $15.2 million was approved to acquire a new system. Approval in FY82 was, in part, a result of the increased national emphasis on illicit drug interdiction and the Vice President's initiatives in the Southeast United States.

The FY82 monies were based on the 1979 plan to refit the LRS fleet with the AN/APS-127 FLAR. The selection of the APS-127 was to provide the Coast Guard with one FLAR for both the LRS and the new MRS, the HU-25A Falcon jet, which was to come into service during the early 1980s. The APS-127 was developed for the HU-25A under a sole source contract awarded to Texas Instruments, based on the Coast Guard's need for a maritime search radar of limited size and weight.

The Coast Guard felt the need for a new LRS radar was so critical that a plan was considered in early 1981 that would divert APS-127 radar sets, already on order as government supplied equipment to the Falcon Jet Company for the HU-25A, to temporary duty on Florida based HC-130s. Unfortunately, by July 1981 it was clear that the APS-127 was in technical trouble. The APS-127 uses a Direct View Storage Tube (DVST)

to accomplish scan to scan integration, a key function required to reduce sea clutter and increase resolution. Hughes aircraft was the subcontractor for the DVST and projected unspecified delivery delays on the bulk of the procurement. The Coast Guard was forced to provide the few APS-127 sets already on hand to the Falcon Jet Company to avoid contract default and loss of the jets' warranty. As each Falcon was delivered, its radar was removed and resupplied to the Falcon Jet Company.

In July 81, The Coast Guard entered into negotiations with the Navy for the purpose of obtaining a new HC-130 FLAR replacement based on a NTNO agreement. The Navy saw value in the retrofit of Coast Guard LRS assets with a FLAR capable of detecting periscope and snorkel target of 1 square meter radar cross section, based on the Coast Guard's military mission. The Navy, through Naval Air Command and with Coast Guard financing, tasked the Naval Air Development Center (NADC) to determine which FLAR would satisfy their mutual requirements and to write a development plan. Appendix E is the executive summary of the <u>Development Plan for C-130 Aircraft Radar Retrofit</u>, dated 12 April 1982, and recommends the AN/APS-134 as the only suitable replacement based on only the 1^2 meter detection capability. It is interesting to note that the executive summary does not discuss the estimated 1982 life cycle cost of $80 million that would be necessary to buy and support 34 radar systems for 25 aircraft.

In October 1982, 23 AN/APN-215 color weather radars were purchased as an interim HC-130 radar. The total APN-215 acquisition cost about $2 million, and the radars would be used to retrofit the MRR, H-3 helicopter, fleet once a permanent LRS FLAR was obtained. During this time, OSR-2, the Aviation (operations) Branch, supported the Navy's APS-134 proposal but EAE, the Aeronautical Engineering Division, was concerned over the complexity and supportability of the system.

In early 1983, some of the APN-215 radars that were bought for the LRS had to be installed in the HU-25, since APS-127 deliveries were still behind schedule. At that time the first new HC-130 replacement aircraft were due for delivery and Lockheed offered to supply AN/APS-133 weather radars as replacement for the pirated APN-215s. This latest development in the radar shell game called for, roughly, half the LRS fleet to have temporary APS-133 radars and half to have APN-215 radars. The HU-25 fleet would have both APS-127 and APN-215 radars.

In late 1983, the Coast Guard Research and Development Center conducted field testing of the APS-127, APS-133 and APN-215 radars [Ref 19], and compared them to tests of the APS-134 conducted by the West German Navy [Ref 20].

In January 84, the OSR-2 HC-130 Program Facility Manager and the EAE Avionics Program Manager visited Naval Air Wing Three of the West German Navy to obtain firsthand knowledge

of how well the APS-134 performed in the maritime/ASW environment of the BR-115Ø aircraft. While findings of these investigations provided some encouraging information on the maintainability and reliability of the APS-134, it did reinforce the EAE contention that the system would require higher levels of maintenance than the Coast Guard had ever experienced. It was decided that the radar's exceptional ability to locate targets down to 1^2 meter overshadowed the expense and difficulties that would be experienced to achieve this performance.

The spring of 1984 marked the beginning of the final formalization of the APS-134 procurement decision as the Navy entered the APS-134 FLAR into its FY86-87 POM cycles, and the Coast Guard requested additional FY86 funds to suppliment its existing FY82 FLAR monies. The procurement schedule would be:

	FY84	FY85	FY86	FY87
Systems	5	-	14	15
Support Equipment	1	-	3	3
Spares	$1.Øm	-	$4.Øm	$4.5m

The Coast Guard Chief, Office of Operations, in a letter sent in July 1984 [Ref 21], provided the Chief, Office of Engineering with a listing of operational requirements for the new LRS radar system. The purpose of this letter was to

provide the FLAR Acquisition Program manager, who is an engineering officer, with a final overview of the required FLAR capabilities desired, before contract negotiations were entered into. The requirements were:

a. The radar must be able to detect a one square meter target from no more than 500 feet altitude in sea state five (Beaufort) at a minimum range of ten miles (fifteen miles desired) with 78% probability of detection.
b. The radar must be able to detect a 100 square meter target from a minimum altitude of 1000 feet in sea state five from a minimum range of 50 miles with 78% probability of detection.
c. The radar must be capable of imaging weather and providing navigational information to a range of 100 miles.
d. The radar shall provide a minimum scan of 180 degrees.
e. The radar and associated equipment must be capable of detecting and interrogating the IFF squawk of aircraft to a range of 100 miles.
f. The radar display and controls must be installed at the Navigator's position without the need to remove any of the equipment currently installed.
g. The radar and associated equipment must be capable of providing latitude and longitude position information of selected targets.
h. It is desired that an additional radar be installed to provide weather detection information to the pilot when the search radar is operating in the search mode.

III. ANALYSIS

The purpose of this chapter is to reaccomplish the analysis that established the need upon which the Coast Guard based its decision to replace the APN-59B FLAR with the APS-134 FLAR. Although Chapter Two provided the reader with historical background data through the summer of 1984, the original Coast Guard FLAR analysis was completed in the spring of 1982. For this reason, the analysis done in this chapter will also work from the 1982 time reference. Therefore, all costs will be in FY82 dollars and the five year operational planning period of FY87-91 will be used. In FY 82, it was believed that this time period represented the first five year period in which a new APS-134 FLAR could be fully operational fleet wide.

The analysis of need performed in this chapter will address the three broad concerns of mission, performance, and cost.

A. MISSION

Chapter Two identified the Search and Rescue, Enforcement of Laws and Treaties, and Military Preparedness missions as the three mission categories that potentially will make the most extensive use of the HC-130 as a search/patrol platform. This section will attempt to add quantified dimensions to the requirements of each of these similar but unique mission categories.

1. <u>Base Line Requirements</u>

For the purpose of this thesis, base line HC-130 requirements are considered to be the total number of operational and spare LRS aircraft necessary to meet all mission categories <u>excluding</u> SAR, ELT and Military Operations. The reason for estimating this figure is to better establish the final impact that various FLAR systems will have on LRS fleet size.

Table 3: Base Line LRS Requirements

	FY87	FY88	FY89	FY90	FY91
Total	26,081	27,937	29,458	29,396	29,193
SAR	6,459	6,451	6,305	6,083	5,880
ELT	10,117	11,891	13,648	13,758	13,758
MILOPS	6	6	6	6	6
Base Line in Hours	9,499	9,499	9,499	9,549	9,549
Base Line in Aircraft	12	12	12	12	12

For the purpose of analysis, minimum LRS fleet size was obtained by subtracting Appendix A; SAR, ELT and Military Operations employment hours from Appendix A; total aircraft employment hour requirements for FY87-91. The results are presented in Table 3. Further, Table 3 base line aircraft estimates are based on 800 annual flight hours

per aircraft. Clearly, all base line missions can be accomplished by a minimum LRS fleet of 12 aircraft. Although, as was discussed in Chapter 2, an actual minimum LRS fleet size of 15 operational and 3 spare aircraft is required to meet the "Bravo Zero" readiness requirement levied on the five LRS air stations.

2. Search and Rescue Requirements

The Coast Guard Search and Rescue Assistance Report (see Appendix E for a sample form and selected portions of the report key) data base for FY83 contains 405, off shore, HC-130 sorties where the time spent searching exceeded on tenth of an hour. In analyzing all FY83 LRS SAR data, 42% of total sortie time was spent searching.

Table 4 presents a summary of the FY83 LRS SAR data broken down into a format based on radar target cross section and sea state (see Appendix F for definitions of sea state).

3. Enforcement of Laws and Treaties Requirements

Data available from the Pacific Area FY83 ELT data base presented few details of interest concerning the ELT mission. Of total time flown, roughly 81% was spent searching or maintaining target surveillance. A target frequency distribution can only be estimated based on the experience of this writer, and is presented in Table 5.

Radar σ In Meters	Target Type	Sorties	Hours Flown	Hours Searched	% Total Hrs Searched	Sea State
	Nonvessel/	73	293.9	158.6	12.5	1
	False Alarm	25	121.3	66.2	5.2	3
<1	And Vessels	26	162.1	77.8	6.1	5
	Less Than	23	117.8	71.2	5.6	>5
	16 Feet	147	695.1	373.8	29.5	subtotal
		41	209.3	145.3	11.5	1
	Vessels	42	229.0	163.0	12.9	3
10	16-39 Feet	47	303.0	185.6	14.7	5
		11	68.8	40.1	3.2	>5
		141	810.1	534.0	42.2	subtotal
		30	154.3	75.9	6.0	1
	Vessels	25	162.8	98.9	7.8	3
50	40-100 Feet	15	82.6	41.4	3.3	5
		17	80.6	36.5	2.9	>5
		87	480.3	252.9	20.0	subtotal
		10	61.9	34.2	2.7	1
	Vessels	8	56.9	34.1	2.7	3
>100	Greater Than	10	55.7	34.5	2.7	5
	100 Feet	2	12.3	2.2	.2	>5
		30	186.8	105.0	8.3	subtotal

Table 4. Summary of FY83 LRS SAR Data

Table 5. Summary of FY83 ELT Estimated Data

Radar Cross Section In Square Meters	Target Type	Time Searched In Percent
10	Vessels 16-39 ft	15
50	Vessels 40-100 ft	55
>100	Vessels over 100 ft	30

4. Military Operations Requirements

LRS protection of the sea lanes during a national emergency would focus almost totally on an anti-submarine role. Targets to be detected would include submarine periscopes and snorkels of approximately 1^2 meter in size. Visual target detection would be very difficult, since the targets would be expected to do all possible to foil detection efforts.

5. Mission Requirements Summary

Only the military mission definitely demands a 1^2 meter FLAR detection capability. While the SAR mission would appear to benefit in 29.5% of all time spent searching, the targets in this category would include rafts, people in the water and small non-metallic boats that would not provide the necessary 1^2 meter radar target cross section in all cases. For small SAR targets visual search is still a viable alternative, since some effort by the

target to be detected (smoke, color, signal mirror, flares, etc.) can be assumed. The ELT mission does not require a detection capability below 10^2 meters radar target cross section.

For only the Coast Guard's "peacetime" missions of SAR and ELT, would it appear possible that a 10^2 meter detection capability could suffice, if performance and cost tradeoffs were necessary. It should be remembered that the Coast Guard approached the Navy concerning an anti-submarine quality FLAR, a point that might lend some focus to overall Navy interest and funding priorities.

But in summary, to accomplish <u>all</u> search/patrol missions satisfactorily a requirement does exist for a FLAR capable of detecting targets of 1^2 meter in radar cross section. This finding is in agreement with the <u>Development Plan for C-130 Aircraft Radar Retrofit</u> [Ref 22] written by the Naval Air Development Center and <u>Evaluation of U.S. Coast Guard Forward-Looking Airborne Radars</u> [Ref 23] written by the U.S. Coast Guard R & D Center.

B. PERFORMANCE

Now that the driving mission requirement to satisfy <u>all</u> search/patrol missions has been established at a 1^2 meter detection capability, it is time to look at each specific radar system.

The FLAR system comparison shown in Table 6 is presented in nautical miles of track spacing required to achieve a 78% probability of detection for a parallel sweep search (Figure 3). For simplicity of computation and the purposes of this thesis, FLAR sweep width was estimated as double the radar detection range, based on an instantaneous single radar sweep encounter, a 78% probability of detection and 10^{-6} probability of false alarm. Performance was computed for targets of 1^2 meter, 10^2 meter, 50^2 meter and 100^2 meter radar cross section by using the range derivative of the basic radar equation (Equation 8 and Swerling case 1 target model charts). FLAR track spacing was calculated by using the random search model (Equation 9) and solving for track spacing, based on a 78% desired probability of detection and the appropriate estimate of FLAR sweep width.

Table 6. Estimates of Track Spacing Based on 78% P_d

σ	Visual	APN59	APS127	APN133	APS134	APS215
1	6.0	2.5 0*	7.3 5.6*	7.5 3.5*	16.2 14.8*	3.7 0*
10	9.2	4.4	13.0	13.3	28.5	6.6
50	10.1	6.7	19.3	19.9	43.3	9.9
100	13.2	7.9	23.0	23.6	51.5	11.7

*indicates preferred value based on operational testing

The Coast Guard visual search model described in Chapter Two was used to provide a reference for comparison, based on a 78% probability of detection for each listed target size. Average, sea state one, search conditions of 1,000 ft. search altitude, 15 miles visibility, 20% cloud cover and 10 knot winds were used to compute visual target sweep widths and track spacing. The reader should recall that the random search model for a parallel sweep search used for FLAR computations, will yield a more conservative estimate than will the inverse cube law model used for the visual computations (see Figure 11).

Research published by the Naval Air Development Command in Flight Test of the AN/APS-116 (XJ-2) Radar [Ref 24], and by the Naval Weapons Center in Airborne ASW Radar Detection: A Consideration of the Operator Factor for the AN/APS-88 Radar Under Low Sea State Conditions [Ref 25], indicate that operator skill and alertness are especially critical during small target encounters. During these encounters radar scope target presentations can be faint, intermittant and are easily masked or misclassified due to sea clutter. As shown in Table 6, data gathered during field testing of selected FLAR systems by the U.S. Coast Guard and West German Navy, reflect serious operational sweep width degradation at the 1^2 meter target size for all but the APS-134. Beyond sea state one, only the APS-134 shows a detection capability against 1^2 meter targets, with a sweep

width of roughly 20 miles in sea state three and 1 mile in sea state five.

1. Performance Comparison

To compare the impact each system would have on resource effort, it is necessary to first establish an estimate for the number of square miles that would be searched using the standard Coast Guard visual search model. This was done by taking the estimated portion of each search/patrol mission category dedicated to search activities and adjusting it by the area that can be searched per LRS hour. Or simply:

$$A = H\ V\ S \tag{10}$$

Where area (A) is in square miles; hours (H) is the total annual time spent searching; aircraft speed (V) is assumed to be 200 knots; and track space (S) is the visual track spacing required to achieve a 78% probability of detection for a visual parallel sweep search.

$$H_{FLAR} = A/VS \tag{11}$$

This total annual search effort (A), now represented in square miles, can be adjusted back into flight hours (H_{FLAR}) by using the track spacing for each FLAR system and the random search model. This is done using Equation 11,

where area (A) is divided by the FLAR track spacing (S) that is required to achieve a 78% probability of detection for a FLAR parallel sweep search, with an aircraft speed (V), which equals 200 knots.

Table 7 compares FLAR technology in the SAR mission category for the years of FY87-91. It recognizes that 42% of total SAR hours are spent searching and that the SAR employment Hours presented in Appendix A are based on visual search capability.

Table 8 compares FLAR technology in the ELT mission category for the years FY87-91. It recognizes that 81% of total ELT hours are spent searching and that the ELT employment hours presented in Appendix A are based on APS-134 search capability. Further, it assumes that a visual search would take at least 50 percent longer than an APS-134 search for medium and large targets [Ref 26].

Since Coast Guard military search/patrol sorties are only conducted during times of national emergency, no sortie time has been programmed into the peacetime projections presented in Appendix A. But, it is estimated that the APS-134 would have at least a three fold track spacing advantage over a visual search conducted in a sea state one environment.

2. <u>Performance Summary</u>

Table 9 summarizes the total impact that FLAR technology is capable of generating in FY87-91. Included in

Table 7. SAR Search Comparison by FLAR System, in Search Hours

Ø	Visual	APN59	APS127	APS133	APS134	APN215	FY
	857	857*	857*	857*	347	857*	87
	868	868*	868*	868*	352	868*	88
1	837	837*	837*	837*	339	837*	89
	808	808*	808*	808*	328	808*	90
	781	781*	781*	781*	317	781*	91
	1227	1227*	1022	1011	396	1227*	87
	1242	1242*	1035	1024	401	1242*	88
10	1197	1197*	1007	987	386	1197*	89
	1155	1155*	963	952	373	1155*	90
	1116	1116*	931	921	360	1116*	91
	581	581*	390	384	136	581*	87
	589	589*	395	388	137	589*	88
50	567	567*	381	375	132	567*	89
	547	547*	368	362	128	547*	90
	529	529*	355	349	123	529*	91
	241	241*	138	135	62	241*	87
	244	244*	140	136	63	244*	88
100	235	235*	135	131	60	235*	89
	227	227*	130	127	58	227*	90
	220	220*	126	123	56	220*	91
	2906	2906	2407	2387	941	2906	87
	2943	2943	2438	2416	953	2943	88
Total	2836	2836	2360	2330	917	2836	89
	2737	2737	2269	2249	887	2737	90
	2646	2646	2193	2174	856	2646	91

* inferior FLAR capability; superceeded by visual capability

Table 8. ELT Search Comparison by FLAR System, in Search Hours

σ	Visual	APN59	APS127	APS133	APS134	APN215	FY
	1844	1844*	1305	1275	595	1844*	87
	2167	2167*	1534	1499	699	2167*	88
10	2487	2487*	1760	1721	803	2487*	89
	2507	2507*	1774	1734	809	2507	90
	2507	2507*	1774	1734	809	2507	91
	6761	6761*	3538	3431	1577	6761*	87
	7946	7946*	4158	4033	1853	7946*	88
50	9120	9120*	4773	4629	2127	9120*	89
	9194	9194*	4811	4666	2145	9194*	90
	9194	9194*	4811	4666	2145	9194*	91
	3638	3638*	2117	2063	945	3638*	87
	4343	4343*	2493	2429	1113	4343*	88
100	4975	4975*	2855	2783	1275	4975	89
	5015	5015*	2878	2805	1285	5015*	90
	5015	5015*	2878	2805	1285	5015*	91
	12293	12293	6960	6769	3117	12293	87
	14478	14478	8185	7961	3665	14478	88
Total	16583	16583	9388	9133	4205	16583	89
	16716	16716	9463	9205	4239	16716	90
	16716	16716	9463	9205	4239	16716	91

* inferior FLAR capability; superceeded by visual capability

Table 9. Total SAR/ELT Flight Hour Comparison by FLAR System

	Visual	APN59	APS127	APS133	APS134	APN215	FY
	6458	6541	5959	5939	4493	6458	87
Total	6541	6541	6036	6014	4551	6541	88
SAR	6304	6304	5828	5798	4385	6304	89
Hours	6083	6083	5615	5595	4233	6083	90
	5880	5880	5427	5408	4090	5880	91
	14629	14629	8882	8691	5039	14629	87
Total	17229	17229	10444	10220	5924	17229	88
ELT	19733	19733	11981	11726	6798	19733	89
Hours	19892	19892	12077	11819	6853	19892	90
	19892	19892	12077	11819	6853	19892	91
	21088	21088	14841	14630	9532	21088	87
	23767	23767	16480	16234	10475	23767	88
Total	26038	26038	17809	17524	11183	26038	89
	26200	26200	17692	17414	11086	26200	90
	25772	25772	17504	17227	10943	25772	91
	26	26	19	18	12	26	87
Required	30	30	21	20	13	30	88
Srch/Ptrl	33	33	22	22	14	33	89
Operation	33	33	22	22	14	33	90
Aircraft	32	32	22	22	14	32	91

Note: Base line LRS fleet size is 12 operational and 3 spare aircraft. Aircraft short fall is in operational aircraft only. Spares would be added at a 1:5 ratio to operational aircraft.

this summary are: The total hours required by each system to accomplish the search/patrol missions of SAR and ELT; total search/patrol hours required and the short fall of 800 hour LRS aircraft required beyond the base line fleet of 12 aircraft.

The information presented in Table 9 serves to reinforce the obvious differences between radar types. The APN-59 and APN-215 were designed as weather radars. Their performance as a search radar is barely on a par with the results that could be obtained by conducting a visual search, given an average day. The APS-127 and APS-133 are roughly equivalent in search performance, with the APS-134 superior to all.

Production effectiveness factors (E_{System}) can be calculated by dividing the total number of visual search/patrol hours required, by the total number of FLAR search/patrol hours required. Table 10 presents the production effectiveness factors for the highest flight hour requirements year of FY90.

Table 10. FLAR Production Effectiveness Factors

	Visual	APN59	APS127	APS133	APS134	APN215
Hours	19453	19453	11732	11454	5126	19453
Factor	1.00	1.00	1.47	1.50	2.35	1.00

C. COST

Before specific FLAR system costs are addressed, it is necesary to further adjust the short fall data for operational aircraft presented in Table 9 to account for

Table 11. Actual LRS Fleet Short Falls

Aircraft	Visual	APN59	APS127	APS133	APS134	APN215	FY
Base Line	12	12	12	12	12	12	87
Search	26	26	19	18	12	26	
Existing	19	19	19	19	19	19	
Short Fall	19	19	12	11	5	19	
Base Line	12	12	12	12	12	12	88
Search	30	30	21	20	13	30	
Existing	19	19	19	19	19	19	
Short Fall	23	23	14	13	6	23	
Base Line	12	12	12	12	12	12	89
Search	33	33	22	22	14	33	
Existing	19	19	19	19	19	19	
Short Fall	26	26	15	15	7	26	
Base Line	12	12	12	12	12	12	90
Search	33	33	22	22	14	33	
Existing	19	19	19	19	19	19	
Short Fall	26	26	15	15	7	26	
Base Line	12	12	12	12	12	12	91
Search	32	32	22	22	14	32	
Existing	19	19	19	19	19	19	
Short Fall	25	25	15	15	7	26	

actual LRS fleet size. As was discussed in Chapter Two, the Coast Guard had an FY84 fleet size of 22 HC-130 aircraft, of which 18 were operational and 4 were spares. Further, 1 aircraft was ordered in FY84 and will bring FY87 fleet size

to 23 aircraft, of which 19 will be operational and 4 will be spare. Table 11 presents the LRS aircraft short fall that results after adjusting for true LRS fleet size. Table 11 was calculated by adding the base line of 12 operational aircraft, to the Table 9 required number of operational aircraft for search patrol, and then subtracting the existing FY87 operational aircraft inventory of 19.

1. FLAR Equipped LRS Costs

The detailed determination of costs in a purchase as large and complex as this project, could serve as a thesis by itself. For this reason heavy reliance has been placed on existing, general cost data. Appendix G is a summary of individual FLAR system costs taken primarily from the Development Plan for C-130 Aircraft Radar Retrofit. Appendix H is a summary of LRS acquisition and operational costs provided by the Budget Division of Coast Guard Headquarters. All cost analysis will be analyzed in FY82 dollars.

FLAR costs assume a worst case scenario that ignores the "Navy type- Navy owned" advantage being sought for the APS-134, where the acquisition, spare parts and periodic depot maintenance costs would be borne by the Navy. This scenario recognizes the low project priority the Navy may have conveyed when, after the Coast Guard approached the Navy, the Navy asked the Coast Guard to fund the retrofit

study. Further, it acknowledges the Coast Guard's willingness to go it alone, if necessary.

FLAR package costing includes: Acquisition and installation of systems for all operational and spare aircraft, to include 5 site spares and 1 training school spare; the operational costs of a maintenance manpower differential, maintenance consumables, component rework and spare parts; and the initial costs of ground support equipment, publications, initial spares and transition training.

LRS costing includes: Air station personnel; the operational variable costs for fuel, aircraft maintenance and depot maintenance; fleet overhead costs for training and administration; and acquisition costs for any operational aircraft and spares necessary beyond the existing FY87 LRS fleet size of 23 HC-130 aircraft.

Four additional assumptions have been made to simplify the basic costing of the FLAR acquisition. One, all FLAR and LRS research development test and evaluation costs are considered sunk. Two, additional recruiting and basic military training costs for any additional personnel required have been ignored. Three, no consideration has been made for additional retirement costs generated by options that expand personnel strength. Four, all additional aircraft will be assigned to existing LRS air stations without concern for air station physical capacity.

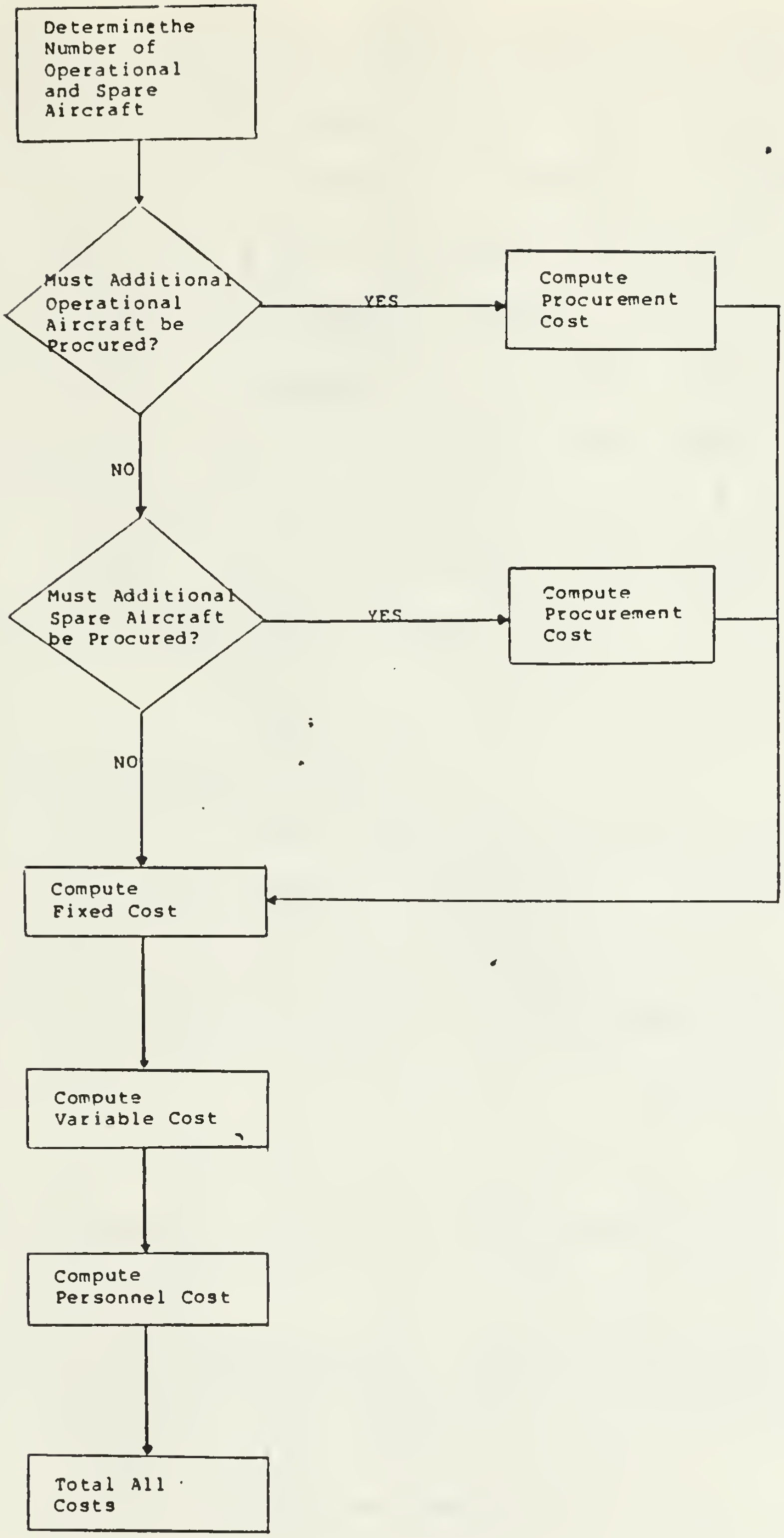


Figure 12. Decision Chart for Determining Total Cost

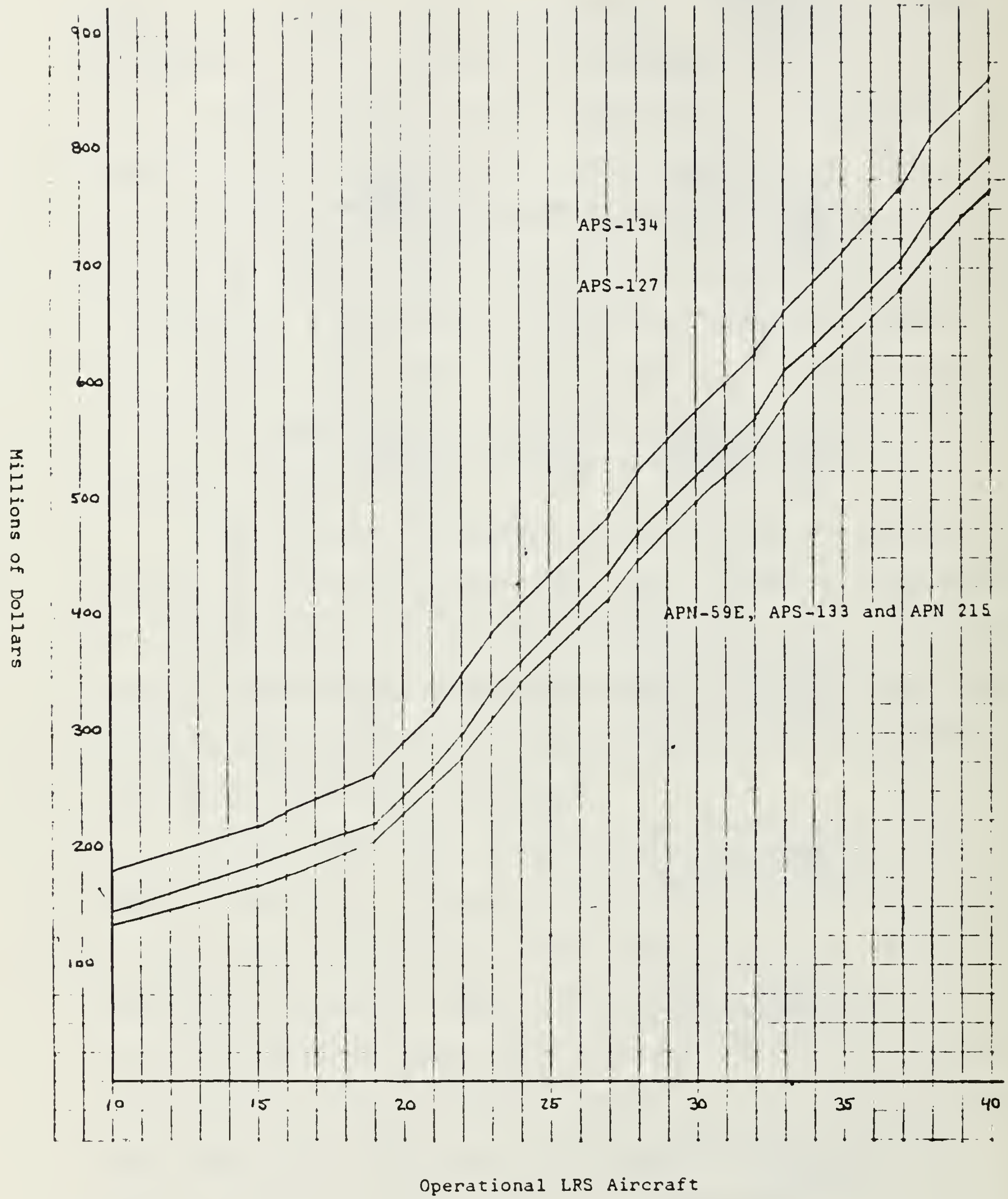


Figure 13. Total Cost of Aircraft by FLAR System

Appendix I provides a table of estimated total costs for operating LRS aircraft under various FLAR configurations for the five year period of FY87-91. Appendix I information was computed using the decision process depicted in Figure 12. Figure 13 provides a graphic summary of the estimated system costs listed in Appendix I. From the Figure 13 depiction of total cost, it can be seen that all FLAR systems examined in this thesis can be summarized into three rough cost curves: The APS-134 curve; the APS-127 curve; and the APN-59E, APS-133 and APN-215 curve.

D. COST EFFECTIVENESS SUMMARY

The final stage of this analysis compares the cost and performance of the APS-134 FLAR against the other systems examined. Figures 14 to 17 present the results.

Levels of equal effectiveness (utility) are given by the expression:

$$U = (E_{APS134})(Q_{APS134}) + (E_{System})(Q_{System}) \qquad (11)$$

Where (E_{APS134}) and (E_{System}) are FLAR System effectiveness factors and (Q_{APS134}) and (Q_{System}) are the number of operational HC-130s equipped with each system.

For peacetime missions, where only a 10^2 meter detection capability is required, all FLARS are considered as perfect substitutes. Thus, there is a constant rate of marginal

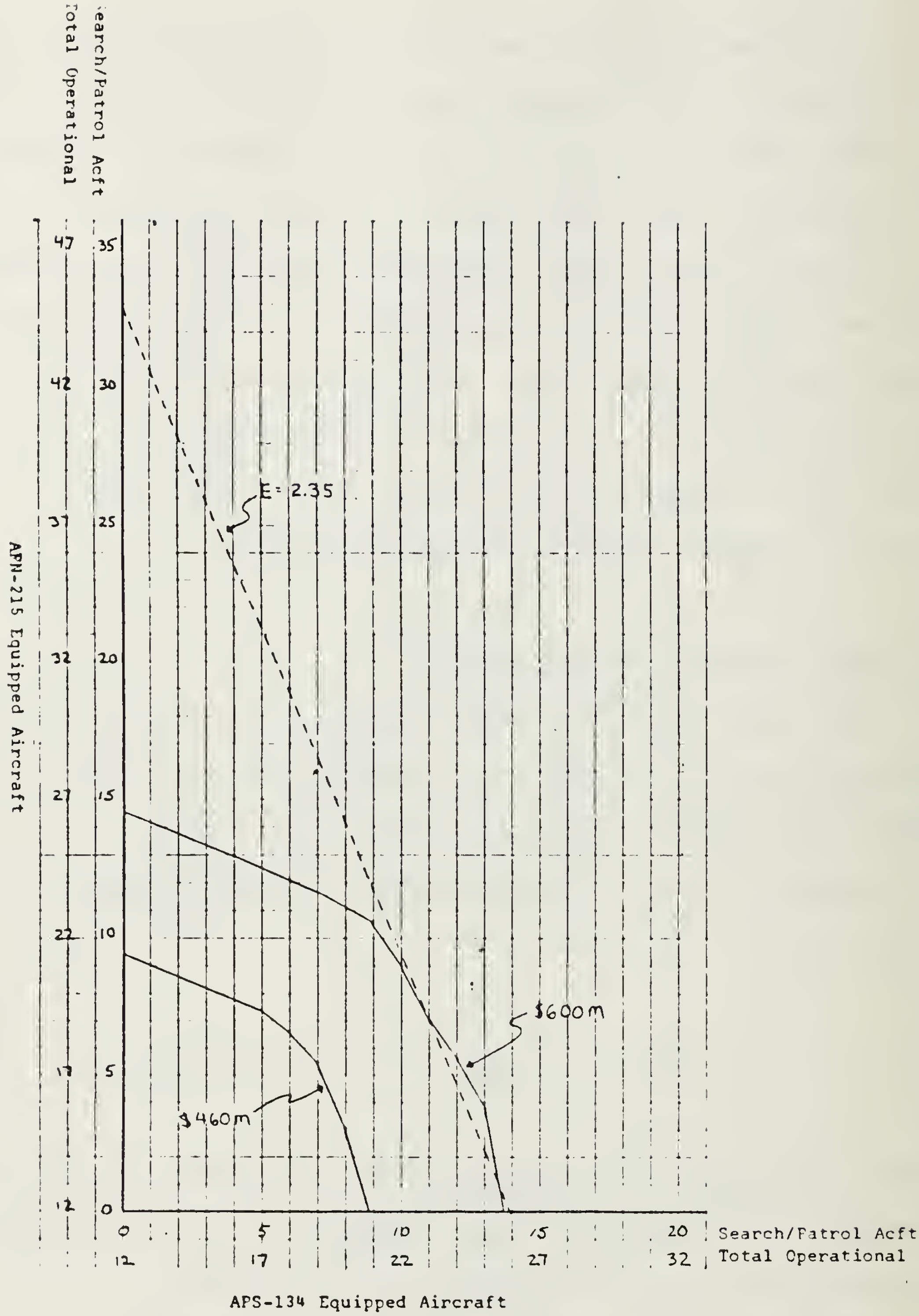


Figure 14. Cost Comparison, APN-59E to the APS-134

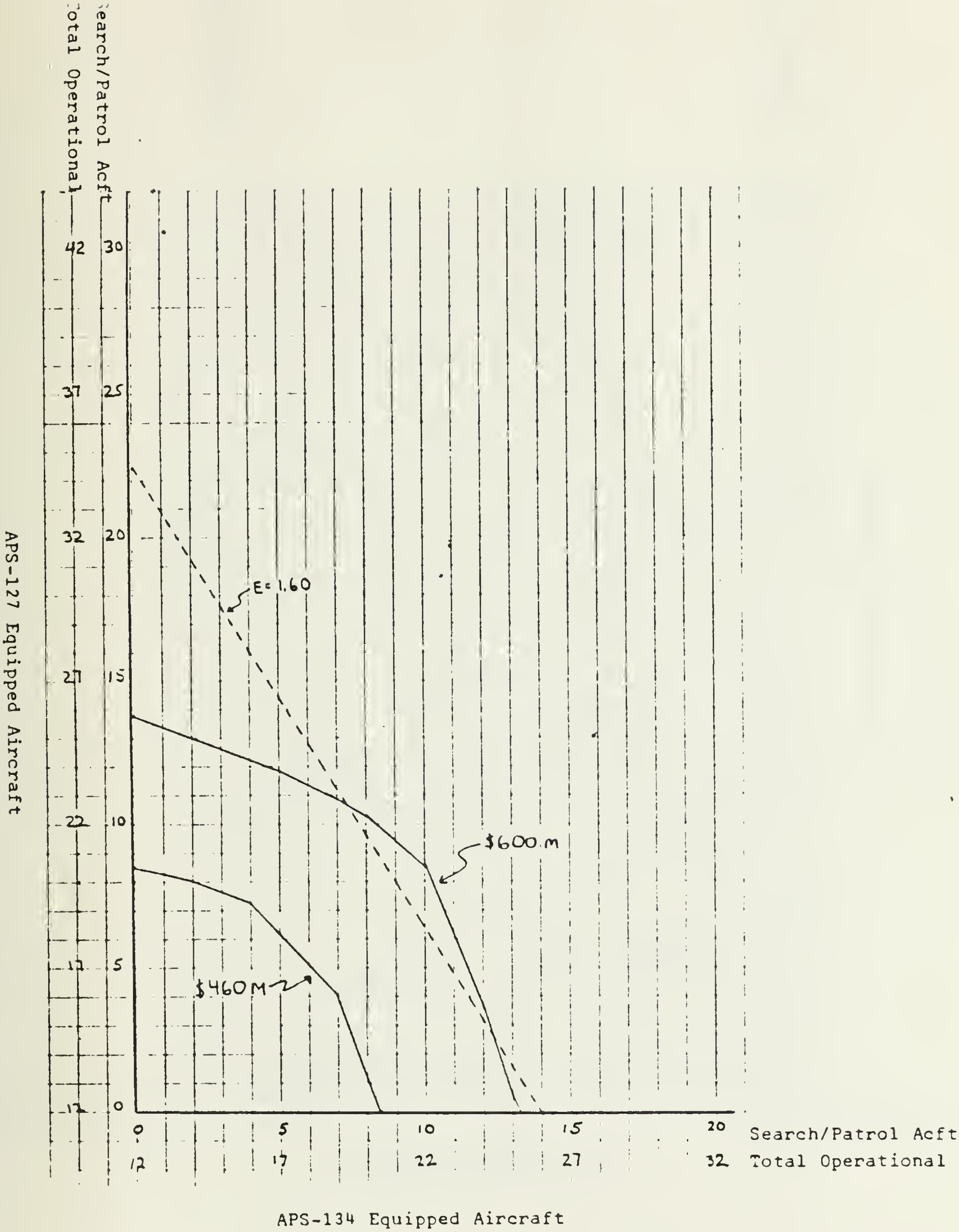


Figure 15. Cost Comparison, APS-127 to the APS-134

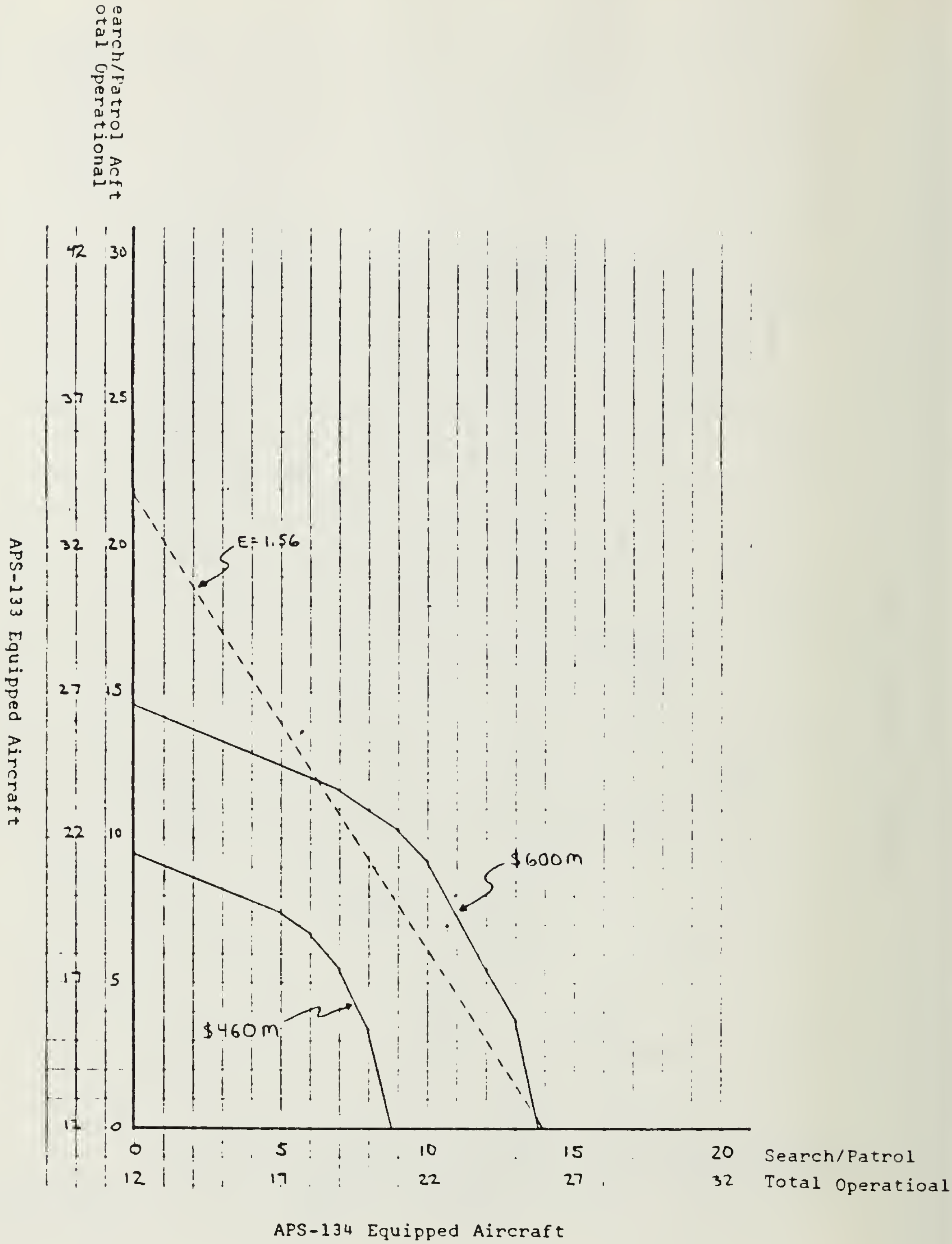


Figure 16. Cost Comparison, APS-133 to the APS-134

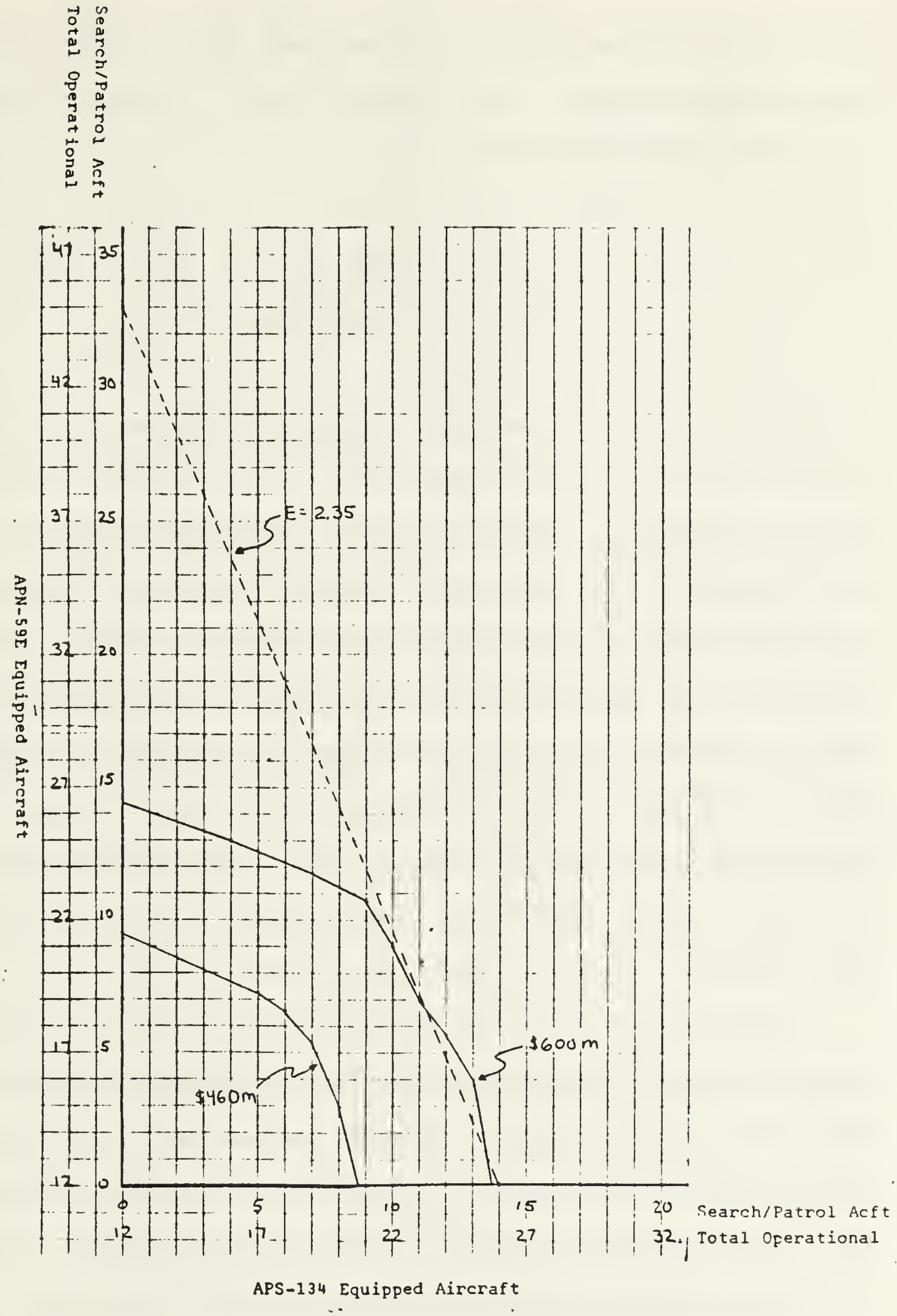


Figure 17. Cost Comparison, APN-215 to the APS-134

substitution resulting in iso-effectiveness lines that plot as straight lines. The slope (M) of the iso-effectiveness lines are calculated by:

$$M = \frac{E_{(APS134)}}{E_{(System)}} \qquad (12)$$

Since all the budget lines are concave and the iso-effectiveness lines are straight, a "qualified corner point" solution exists. This means that based on the <u>single</u> performance factor of search capability, an all APS-134 LRS fleet should be pursued; but, pursued only to the point necessary to meet the minimum search/patrol requirements. Should funding allow the purchase of aircraft in excess of those needed to meet search/patrol mission requirements, these additional aircraft do not have to be APS-134 equipped to be of value. A mixed force might be more rational at that point.

Specifically, for this analysis it has already been established in Table 11 that 7 additional operational LRS aircraft are necessary, based on specific search/patrol flight hour requirements. Using Figure 14 as an example of how each comparison graph is used, enter at the X intercept of 14 operational, search/patrol, APS-134 equipped aircraft (26 operational aircraft when the 12 base line aircraft are added). Following up the iso-effectiveness line, it can be

seen that roughly 33 operational, search/patrol, APN-59E equipped aircraft (45 total operational) would be necessary to do the same job. Looking at the budget curves, it can be seen that 26 operational APS-134 LRS aircraft would cost roughly $460 million to buy (assume original owneship of 19 operational aircraft) and operate for the five year period, versus roughly $900 million for the 45 operational APN-59E equipped LRS aircraft capable of doing only the same workload.

Should funding be available past that amount necessary to field 26 operational APS-134 aircraft, it might not always be rational to buy additional APS-134 equipped LRS aircraft. Should $525 million be available, for example, three APN-59E eqiupped aircraft could be purchased in the place of two extra APS-134 equipped aircraft. This point is especially important if a secondary performance standard is in effect, such as maximizing LRS fleet cargo hauling capacity. In this hypothetical case, a mixed fleet of 29 operational aircraft would be best.

The basic assumptions used to simplify the cost analysis would only lend more weight to the results presented. The cost of expanding LRS air station facilites to accomodate 45 operational LRS aircraft would be cost prohibitive by itself. Likewise, if the Navy does finally provide the APS-134 as a "free good" through a Navy Type-Navy Owned agreement, it would further restrict any other rational substitute.

IV. CONCLUSIONS AND RECOMMENDATIONS

The Coast Guard should continue actively pursing the acquisition of the APS-134 for retrofit into existing HC-130 LRS aircraft. The APS-134 is the only FLAR analyzed that meets the search/patrol mission criteria of a detection capability of 1^2 meter radar target cross section in conditions up to sea state five. Further, of the systems examined, it is the most cost effective solution to meet the LRS search/patrol requirements projected through the end of this decade.

Should the Coast Guard find it necessary to fund the APS-134, instead of the Navy, one word of caution should be added. If the newly approved LRS fleet (effective in FY85, the wording of the authorization is unclear) actually refers to operational aircraft, instead of a total aircraft ceiling, the Coast Guard could field 27 operational plus 5 spare LRS aircraft. Great care should be taken to fully analyze both the primary performance need of search/patrol, as well as other performance needs that might find a larger, mixed LRS fleet more advantagous. Or, since no additional funding accompanied the LRS fleet ceiling hike, it might be wise to consider holding the LRS fleet at 26 operational and 5 spare aircraft, the optimal to meet forecast search/patrol requirements.

All LRS pilots and search planners must be provided with the proper training and search planning materials necessary to effectively utilize the capabilities of advanced Coast Guard FLAR sensors. Reliance on the visual model and its associated planning materials will no longer provide reliable estimates upon which to plan searches or evaluate results.

Finally, the model used to calculate the probability of dsetection for parallel sweep searches should be standardized for both visual and FLAR searches. It is recommended that the random search model be used. The recommended random searchm model yields a 63% probability of detection for a coverage factor of 1 and a 78% probability of detection at a coverage factor of 1.5. By comparison the current Coast Guard visual model yields a 78% probability of detection for a coverage factor of 1 and a 90% probability of detection for a coverage factor of 1.5. This readjustment downward of the detection probabilities (see Figure 11) would more accurately reflect operational performance realities.

TOTAL LRS EMPLOYMENT HOUR REQUIREMENTS FY87-91

TOTAL AIRCRAFT EMPLOYMENT HOUR REQUIREMENTS, BY PROGRAM
FISCAL YEAR 87

Program	SRR	MRR	MRS	LRS	OTHER	TOTAL
	Aircraft Type					
ELT	0	0	14415	10117	0	24532
IO	210	30	0	657	0	897
MER	1085	761	650	304	0	2800
MO/MP	15	12	18	6	0	51
PES	230	13	9248	2	0	9493
RA	49	51	0	1080	0	1180
SAR	9314	4702	3909	6459	0	24384
SRA	1710	1332	44	522	0	3608
GAB	245	82	110	418	0	855
COOP	594	209	201	164	0	1168
FERRY	408	173	89	308	0	978
OPTRA	17795	7034	7419	5003	0	37251
TEST	1220	494	384	266	0	2364
MISC	700	266	1282	775	0	3023
TOTAL	33575	15159	37769	26081	0	112584

Note: Table does not include special aircraft requirements which are developed independantly.

TOTAL AIRCRAFT EMPLOYMENT HOUR REQUIREMENTS, BY PROGRAM
FISCAL YEAR 88

Program	SRR	MRR	MRS	LRS	OTHER	TOTAL
	Aircraft Type					
ELT	0	0	14445	11891	0	26336
IO	210	30	0	657	0	897
MER	1085	761	650	304	0	2800
MO/MP	15	12	18	6	0	51
PES	230	13	9248	2	0	9493
RA	49	51	0	1080	0	1180
SAR	9467	4771	3965	6541	0	24743
SRA	1710	1332	44	522	0	3608
GAB	245	82	110	418	0	855
COOP	594	209	201	164	0	1168
FERRY	408	173	89	308	0	978
OPTRA	17795	7034	7419	5003	0	37251
TEST	1220	494	384	266	0	2364
MISC	700	266	1282	775	0	3023
TOTAL	33728	15228	37854	27937	0	114747

TOTAL AIRCRAFT EMPLOYMENT HOUR REQUIREMENTS, BY PROGRAM
FISCAL YEAR 89

Program	SRR	MRR	MRS	LRS	OTHER	TOTAL
	Aircraft Type					
ELT	0	0	14445	13648	0	28093
IO	210	30	0	657	0	897
MER	1085	761	650	304	0	2800
MO/MP	15	12	18	6	0	51
PES	230	13	9248	2	0	9493
RA	49	51	0	1080	0	1180
SAR	9623	4845	4021	6305	0	24794
SRA	1710	1332	44	522	0	3608
GAB	265	92	110	418	0	885
COOP	594	209	201	164	0	1168
FERRY	408	173	89	308	0	978
OPTRA	17795	7034	7419	5003	0	37251
TEST	1220	494	384	266	0	2364
MISC	700	266	1282	775	0	3023
TOTAL	33904	15312	37910	29458	0	116584

TOTAL AIRCRAFT EMPLOYMENT HOUR REQUIREMENTS, BY PROGRAM
FISCAL YEAR 90

Program	SRR	MRR	MRS	LRS	OTHER	TOTAL
	Aircraft Type					
ELT	0	0	14505	13758	0	28263
IO	210	30	0	707	0	947
MER	1085	761	650	304	0	2800
MO/MP	15	12	18	6	0	51
PES	230	13	9248	2	0	9493
RA	49	51	0	1080	0	1180
SAR	9781	4918	4081	6083	0	24863
SRA	1710	1332	44	522	0	3608
GAB	315	102	110	418	0	945
COOP	594	209	201	164	0	1168
FERRY	408	173	89	308	0	978
OPTRA	17795	7034	7419	5003	0	37251
TEST	1220	494	384	266	0	2364
MISC	700	266	1282	775	0	3023
TOTAL	34112	15395	38030	29396	0	116933

TOTAL AIRCRAFT EMPLOYMENT HOUR REQUIREMENTS, BY PROGRAM
FISCAL YEAR 91

Program	Aircraft Type SRR	MRR	MRS	LRS	OTHER	TOTAL
ELT	0	0	14505	13758	0	28263
IO	210	30	0	707	0	947
MER	1085	761	650	304	0	2800
MO/MP	15	12	18	6	0	51
PES	230	13	9248	2	0	9493
RA	49	51	0	1080	0	1180
SAR	9942	4990	4141	5880	0	24953
SRA	1710	1332	44	522	0	3608
GAB	315	102	110	418	0	945
COOP	594	209	201	164	0	1168
FERRY	408	173	89	308	0	978
OPTRA	17795	7034	7419	5003	0	37251
TEST	1220	494	384	266	0	2364
MISC	700	266	1282	775	0	3023
TOTAL	34273	15467	38090	29193	0	117023

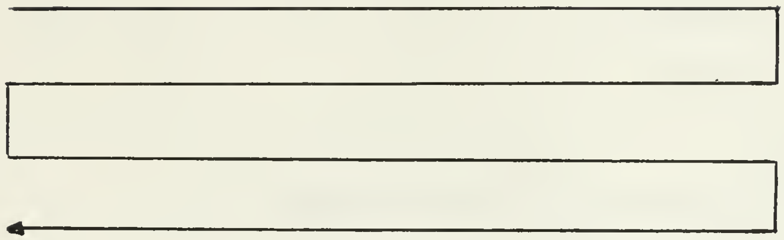
AIRCRAFT REQUIREMENTS
FY87-FY91

AIRCRAFT TYPE	FACILITY MANAGER	87	88	89	90	91	OPP/SPP GOALS SUPPORTED
SRR	G-OSR						SAR(1)ELT(I-1&2&3,II-1&2),IO(1&4),MER(1) MO/MP,RA,SRA(2), GAB,GAP,GRD
Required		113	112	111	111	111	
Have		94	93	92	91	90	
Shortage/(Surplus)		19	19	19	20	21	
MRR	G-OSR						SAR(1),IO(4),MER(1) MO/MP,RA,SRA(2) GAB,GAP,GRD
Required		37	37	37	37	37	
Have		7	0	0	0	0	
Shortage/(Surplus)		30	37	37	37	37	
MRS	G-OSR						SAR(1)ELT(I-1&2&3,II-1&2),IO(1&4),MER(1) MO/MP,PES(4),SRA(2) GAB,GAP,GRD
Required		49	49	48	48	48	
Have		41	41	41	40	40	
Shortage/(Surplus)		8	8	7	8	8	
LRS	G-OSR						SAR(1),ELT(I-1&2&3, II-1&2)IO(1&4),MER(1) MO/MP,RA,SRA(2), GAB,GAP,GRD
Required		37	40	40	40	40	
Have		23	23	23	23	23	
Shortage/(Surplus)		14	17	17	17	17	

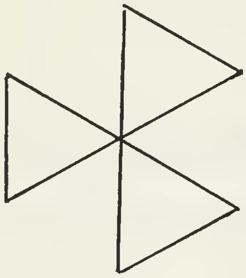
APPENDIX B

SEARCH PATTERNS

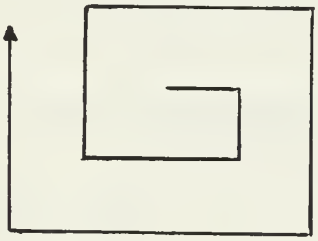
Parallel search



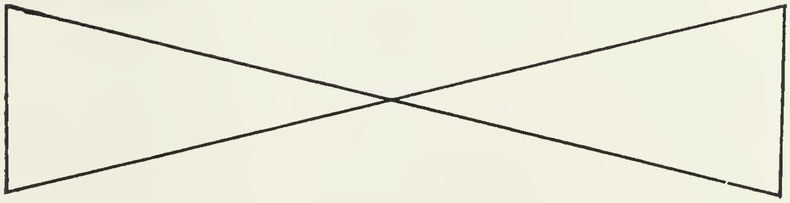
Sector Search



Expanding Square Search



Barrier Search



APPENDIX C

SAMPLE RADAR CROSS SECTIONS

Submarine Periscope	1
Submarine Snorkel	1
Boston Whaler	1
16 Foot Fiberglass Boat with Outboard	1
30 Foot Cabin Crusier	10
60 Foot Fishing Boat	50-500
Freighter	1000-10000
Tanker	2500-12000
8X26 Lighted Buoy with Radar Reflector	100-35000
2nd Class Can Buoy with Radar Reflector	50-12000
Corporate Jet	5-1000
Airliner	50-10000

Note: All figures are in square meters of radar target cross section.

APPENDIX D

FLAR TECHNICAL DATA

Technical Data for the AN/APN-59E FLAR

TRANSMITTER:

Frequency	9375 MHz
Peak Power	70 KW
Pulse Width	0.35 μs; 4.5 μs
PRF	1900 Hz; 180 Hz

RECEIVER:

Type	LINEAR; STC - Adjustable Range/Depth to 40 nmi
Noise Figure	9.5 dB
IF Center Freq.	
IF Bandwidth	6.5 MHz; 1 MHz

ANTENNA:

Gain	30.5 dB
Size	
Beamwidth (AZ x EL)	3° x 5°
Peak Sidelobe	
Polarization	Horizontal
Scan Rate	45 rpm; 15 rpm

DISPLAY: Storage type CRT; PPI format

WEIGHT: 180 lbs.

PRIME POWER: 115 VAC; 400 Hz 12A
25 VDC; 6A

VOLUME: 4.53 Cubic Feet

Technical Data for the AN/APS-127

TRANSMITTER:

Frequency	9.05 GHz with 60 MHz Agility
Peak Power	200 KW
Pulse Width	0.5 μs; 2.5 μs
PRF	1600 Hz; 400 Hz

RECEIVER:

Type	Logarithmic with STC & FTC
Noise Figure	7.5 dB
IF Center Freq.	60 MHz
IF Bandwidth	2.5 MHz; 0.5 MHz

ANTENNA:

Gain	30.5
Size	29" x 17" Planar Plate
Beamwidth (AZ x EL)	5.0° x 6.5°
Peak Sidelobe	20 dB below mainlobe
Polarization	Horizontal
Scan Rate	120 rpm; 12 rpm

DISPLAY: Direct View Storage Tube; PPI format

WEIGHT: 295.5 lbs

PRIME POWER: 115 VAC; 3 phase, 400 Hz, 1950 VA 28 VDC; 3A

VOLUME: 8.25 Cubic Feet

Technical Data for the AN/APS-133 FLAR

TRANSMITTER:

Frequency	9375 MHz
Peak Power	65 KW
Pulse Width	0.5 μs; 5 μs
PRF	200 Hz

RECEIVER:

Type	Linear with STC & AGC
Noise Figure	7.5 dB
IF Center Freq.	
IF Bandwidth	2 MHz; 200 KHz

ANTENNA:

Gain	33 dB
Size	30" Parabola
Beamwidth (AZ x EL)	2.9° x 2.9°
Peak Sidelobe	
Polarization	Horizontal
Scan Rate	45°/sec within $\pm$ 90° about boresight

DISPLAY: CRT driven from digital memory; PPI format

WEIGHT: 114 lbs

PRIME POWER: 115 VAC; 400 Hz; 600 VA

VOLUME: 1.29 Cubic Feet

Technical Data for the AN/APS-134 FLAR

TRANSMITTER:

Frequency	9.5 - 10 GHz
Peak Power	500 KW
Pulse Width	0.5 µs
PRF	2000 Hz; 500 Hz

RECEIVER:

Type	Pulse Compression with AGC
Noise Figure	5.5 dB
IF Center Freq.	1300 MHz
IF Bandwidth	500 MHz
Pulse Compression Ratio	167:1
Compressed Pulsewidth	3 ns

ANTENNA:

Gain	35 dB
Size	42" x 26" Parabola
Beamwidth (AZ x EL)	2.4° x 4.0°
Peak Sidelobe	20 dB below mainlobe
Polarization	Horizontal
Scan Rate	150 rpm; 40 rpm

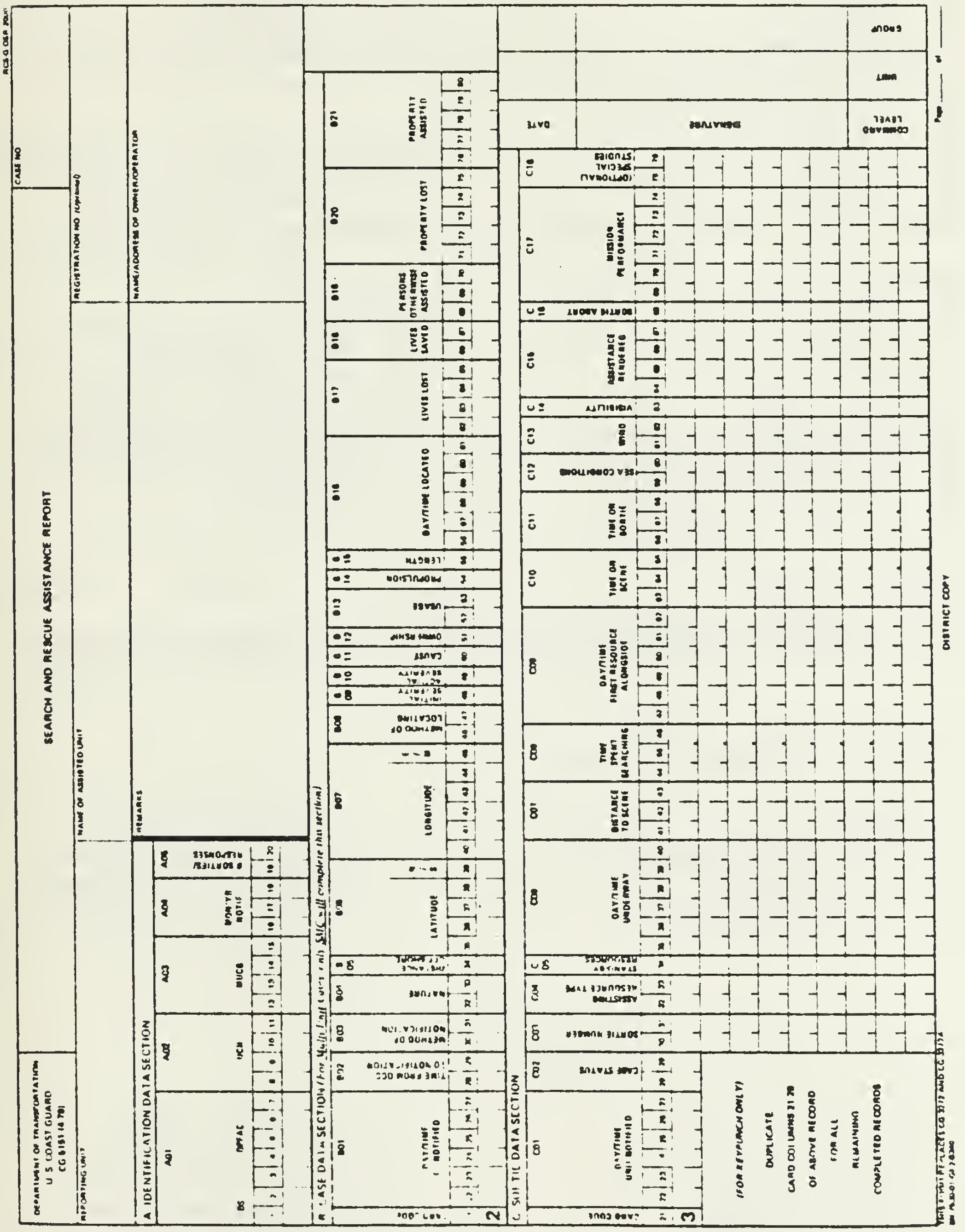
DISPLAY: MPD Driven by Scan Converter; PPI format

WEIGHT: 527 lbs

PRIME POWER: 115 VAC; 3 Phase, 400 Hz, 5.4 KVA

VOLUME: 8.87 Cubic Feet

SEARCH AND RESCUE ASSISTANCE REPORT AND PARTIAL KEY


RCS-G-OSR-2020
DEPARTMENT OF TRANSPORTATION
U S COAST GUARD
CG 5151 (4-78)
SEARCH AND RESCUE ASSISTANCE REPORT
CASE NO
REPORTING UNIT
NAME OF ASSISTED UNIT
REGISTRATION NO (Optional)
A IDENTIFICATION DATA SECTION
REMARKS
NAME/ADDRESS OF OWNER/OPERATOR
A01 DS OPFAC
A02 UCN
A03 MUCS
A04 MON/YR NOTIF
A05 # SORTIES/ RESPONSES
B CASE DATA SECTION (For Multi Unit Cases only SMC will complete this section)
CARD CODE
B01 DAY/TIME NOTIFIED
B02 TIME FROM OCC TO NOTIFICATION
B03 METHOD OF NOTIFICATION
B04 NATURE
B05 DISTANCE OFFSHORE
B06 LATITUDE
B07 LONGITUDE
B08 METHOD OF LOCATING
B09 INITIAL SEVERITY
B10 ACTUAL SEVERITY
B11 CAUSE
B12 OWNERSHIP
B13 USAGE
B14 PROPULSION
B15 LENGTH
B16 DAY/TIME LOCATED
B17 LIVES LOST
B18 LIVES SAVED
B19 PERSONS OTHERWISE ASSISTED
B20 PROPERTY LOST
B21 PROPERTY ASSISTED
C SORTIE DATA SECTION
CARD CODE
C01 DAY/TIME UNIT NOTIFIED
C02 CASE STATUS
C03 SORTIE NUMBER
C04 ASSISTING RESOURCE TYPE
C05 STANDBY RESOURCES
C06 DAY/TIME UNDERWAY
C07 DISTANCE TO SCENE
C08 TIME SPENT SEARCHING
C09 DAY/TIME FIRST RESOURCE ALONGSIDE
C10 TIME ON SCENE
C11 TIME ON SORTIE
C12 SEA CONDITIONS
C13 WIND
C14 VISIBILITY
C15 ASSISTANCE RENDERED
C16 SORTIE ABORT
C17 MISSION PERFORMANCE
C18 (OPTIONAL) SPECIAL STUDIES
DATE
SIGNATURE
COMMAND LEVEL
UNIT
GROUP
(FOR KEYPUNCH ONLY)
DUPLICATE CARD COLUMNS 21-29 OF ABOVE RECORD FOR ALL REMAINING COMPLETED RECORDS
THIS FORM REPLACES CG 3272 AND CG 3272A
DISTRICT COPY
Page ___ of ___

A PARTIAL KEY FOR THE SAR ASSISTANCE REPORT

Block B04: Nature of the Incident

Vessel
- 01 Disabled/adrift
- 02 Aground
- 03 Capsized
- 04 Fire/explosion
- 05 Flooding/sinking
- 06 Collision
- 07 Lost/disoriented
- 08 Beset in ice
- 09 Other condition

Aircraft
- 21 Ditch/forced landing
- 22 Crash
- 23 Low on fuel
- 24 Bail out
- 25 Fire/explosion
- 26 Mechanical casualty
- 27 Lost/disoriented
- 29 Other condition

Land Vehicle
- 41 Collision
- 42 Disabled
- 47 Lost
- 49 Other Condition

Land or Offshore Structure
- 51 Flooding
- 52 Fire/explosion
- 53 Other Condition

Personnel
- 71 Personnel in water
- 72 Man overboard
- 73 Swimmer in danger
- 74 Sickness/injury
- 75 Diver in distress
- 77 Lost/stranded
- 78 Medivac
- 79 Other condition

Special Condition
- 91 Overdue
- 99 Case evaluated either as a false alarm or hoax

Block B05: Distance Offshore

- 0 Land
- 1 Inland waterways
- 2 0 to 3 miles
- 3 3 to 10 miles
- 4 10 to 20 miles
- 5 20 to 50 miles
- 6 50 to 100 miles
- 7 100 to 150 miles
- 8 150 to 300 miles
- 9 Greater than 300 mile

Block B15: Length of Assisted Vessel

- 0 Other tah vessel/ false alarm
- 1 less than 16 feet
- 2 16 to 25 feet
- 3 26 to 39 feet
- 4 40 to 65 feet
- 5 66 to 100 feet
- 6 101 to 200 feet
- 7 201 to 300 feet
- 8 Greater than 300 feet

Block CØ7: Distance to Scene (Search Area)

The actual distance traveled from homeport, station, patrol area or diversion point to the nearest mile.

Block CØ8: Time Spent Searching

Actual time spent searching to the tenth of an hour.

Block C11: Time on Sortie

Actual total time spent iunderway or airborne to the tenth of an hour.

Block C12: Sea Conditions

Greatest wave height to the nearest foot seen during the sortie.

Block C13: Wind

Greatest wind speed encountered during the sortie in Knots.

Block C14: Visibility

Lowest visibility to the mile encountered during the sortie.

APPENDIX F

SEA STATE SUMMARY

SEA STATE	SEA INDICATIONS DESCRIPTION	WIND DESCRIPTION	WIND VELOCITY RANGE (KNOTS)	WAVES: WAVE HEIGHT IN FEET AVERAGE	WAVES: WAVE HEIGHT IN FEET MAXIMUM
0	Sea may look like a mirror or small ripples with appearance of scales, but without foam crest.	Calm to light airs	0-3	0	Less than 6 inches
1	Wavelets that are short but pronounced. Crests may begin to break. Perhaps very few scattered whitecaps.	Light to gentle breeze	4-9	6 inches	1
2	Large wavelets or small waves becoming larger. Fairly frequent whitecaps.	Gentle to moderate breeze	10-13	2	3
3	Small waves becoming larger. Frequent whitecaps.	Moderate breeze	14-16	3	5
4	Moderate waves, pronounced long foam. Many whitecaps. Chance of some spray.	Fresh breeze	17-19	4.5	7
5	Moderate to large waves form. White foam crests are more extensive everywhere. Probability of some spray.	Fresh to strong breeze	20-24	8	12
6	Large waves. Sea heaps up. White foam from breaking waves begins to be blown in streaks along the direction of the wind. May begin to see spindrifts	Strong breeze	25-28	11	18
7	Sea heaps up. Streaks along the direction of wind. Moderately high waves of greater length. Edges of crest break into spindrift. The foam is blown in well marked streaks along wind direction.	Moderate to fresh gale	29-38	25	40
8	High waves. Dense streaks of foam along the direction of wind. Sea begins to roll. Visibility limited. Note: for conditions above these limits, use Whole Gale, Storm, or Hurricane definition.	Strong gale	39-44	36	58

APPENDIX G

SUMMARIZED COSTS,
DEVELOPMENT PLAN FOR C-130 AIRCRAFT RADAR RETROFIT

FLAR FIXED COSTS

A. FLAR fixed costs assume an initial investment to cover: publications,; ground support and test equipment; initial spares; transition training; plus 6 FLAR systems, 5 for air station spares and 1 for the training school.

B. The cost by system:

1. APN-59E $1,335,000
2. APS-127 $9,343,000
3. APS-133 $1,312,000
4. APS-134 $28,906,000
5. APN-215 $1,050,000

FLAR PROCUREMENT COSTS

A. Procurement cost includes the cost per aircraft to acquire and install the system on all operational and spare LRS aircraft.

B. The cost by system:

1. APN-59E $57,800
2. APS-127 $412,500
3. APS-133 $60,500
4. APS-134 $1,206,300
5. APN-215 $52,000

FLAR VARIABLE COSTS

A. Variable costs are for a five year perid and cover a maintainance manpower differential, consumables, component rework and replenishable spares.

B. The cost by system:

1. APN-59E $27,600
2. APS-127 $9,342,000
3. APS-133 $1,312,000
4. APS-134 $28,906,000
5. APN-215 $1,050,00

APPENDIX H

SUMMARIZED COST DATA; BUDGET DIVISION, COAST GUARD HEADQUARTERS

LRS FIXED COSTS

A. Fixed costs cover five years of service wide support costs to incude:

1. ATTC
2. AR&SC
3. SUPTCEN E-City
4. HQ-EAE
5. HQ-OSR2
6. Naval aviator training
7. Misc costs

B. $942,677 for 18 operational aircraft and adjusted by 1% for each additional operational aircraft.

LRS PROCUREMENT COSTS

A. Procurement costs assume the cost of purchasing LRS number 1790 reflects the FY82 market value of a fully equipped LRS. Further, a 1:5 ratio of spares to operational aircraft is assumed.

B. $14,500,000 per aircraft

LRS VARIABLE COSTS

A. Variable costs are based on fuel, maintenance and the aircraft program costs for a five year period.

B. $1746 per flight hour for $6,984,000 per 800 hour aircraft.

LRS PERSONNEL COSTS

A. Personnel costs assume a base line requirement for 15 (Bravo 0 requirement) operational aircraft operated from five locations. Additional operational aircraft past 18 will add 18 enlisted and 3 officer. Personnel costs cover a five year period.

B. $61,340,000 base line plus $2,255,00 per additional operational aircraft.

LRS TOTAL COST TABLE, BY FLAR SYSTEM

Aircraft Operational Spare Total	APN-59	APS-127	APS-133	APS-134	APN-215	Cost
	2205	10212	2182	29776	1920	Fixed
10	70116	70840	69980	73150	70088	Variable
2	61340	61340	61340	61340	61340	Personnel
12	694	4950	726	14475	630	Procurement
	134355	147342	134228	178741	133978	Total
	2214	10221	2191	29785	1929	Fixed
11	77127	77924	76978	80465	77096	Variable
2	61340	61340	61340	61340	61340	Personnel
13	751	5363	787	15682	623	Procurement
	141432	154848	141296	187272	140988	Total
	2222	10229	2199	29793	1937	Fixed
12	84139	85008	83976	87780	84105	Variable
2	61340	61340	61340	61340	61340	Personnel
14	809	5775	847	16888	735	Procurement
	148510	162352	148362	195801	148117	Total
	2231	10238	2208	29802	1946	Fixed
13	91150	92092	90974	95095	91114	Variable
3	61340	61340	61340	61340	61340	Personnel
16	925	6600	968	19301	840	Procurement
	155646	170270	155490	205538	155240	Total
	2240	10247	2217	29811	1955	Fixed
14	98162	99176	97972	102410	98123	Variable
3	61340	61340	61340	61340	61340	Personnel
17	983	7013	1029	20507	893	Procurement
	162725	177776	162558	214068	107105	Total
	2249	10256	2226	29820	1964	Fixed
15	105174	106260	104970	109725	105132	Variable
3	61340	61340	61340	61340	61340	Personnel
18	1040	7425	1089	21713	945	Procurement
	169803	185281	169625	222599	169381	Total

	2258	10265	2235	29829	1973	Fixed
16	112185	113344	111968	117040	112140	Variable
3	61340	61340	61340	61340	61340	Personnel
19	1098	7838	1150	22920	998	Procurement
	178936	195042	178948	233384	178706	Total
	2267	10274	2244	29838	19821	Fixed
17	119197	120428	118966	124355	119149	Variable
3	65850	65850	65850	65850	65850	Personnel
20	1156	8250	1210	24126	1050	Procurement
	188470	204802	188270	244169	188031	Total
	2277	10284	2254	29848	1992	Fixed
18	126208	127512	125964	131670	126158	Variable
3	68105	68105	68105	68105	68105	Personnel
21	1214	8663	1271	25332	1103	Procurement
	197804	214564	197594	254955	197358	Total
	2287	10294	2264	29858	2002	Fixed
19	133220	134596	132962	138985	133167	Variable
4	70360	70360	70360	70360	70360	Personnel
23	1329	9488	1392	27745	1208	Procurement
	209196	224738	206978	266948	206737	Total
	2296	10303	2273	29867	2011	Fixed
20	140232	141680	139960	146300	140176	Variable
4	72615	72615	72615	72615	72615	Personnel
24	15887	24400	15952	43451	15760	Procurement
	231030	248998	230800	292233	230562	Total
	2306	10313	2283	29877	2021	Fixed
21	147243	148764	146958	153615	147184	Variable
4	74870	74870	74870	74870	74870	Personnel
25	30445	39313	30513	59158	30313	Procurement
	254864	273260	254624	317520	254388	Total
	2315	10322	2292	29886	2030	Fixed
22	154255	155848	153956	160930	154193	Variable
4	77125	77125	77125	77125	77125	Personel
26	45003	54225	45073	74864	44865	Procrement
	287698	297520	278446	342805	278213	Total
	2325	10332	2302	29896	2040	Fixed
23	161266	162932	160954	168245	161202	Variable
5	79380	79380	79380	79380	79380	Personnel
28	74118	84050	74194	106276	73970	Procurement
	317089	336694	316830	383797	316592	Total

	2335	10342	2312	29906	2050	Fixed
24	168278	170016	167952	175560	168211	Variable
5	81635	81635	81635	81635	81635	Personnel
29	88676	98963	88755	121983	88523	Procurement
	340924	360956	340654	409084	340419	Total
	2345	10352	2322	29916	2060	Fixed
25	175290	177100	174950	182875	175220	Variable
5	83890	83890	83890	83890	83890	Personnel
30	103234	113875	103315	137689	103075	Procurement
	364759	385217	364477	434370	364245	Total
	2355	10362	2332	29926	2070	Fixed
26	182301	184184	181948	190190	182228	Variable
5	86145	86145	86145	86145	86145	Personnel
31	17792	128788	117876	153395	116000	Procurement
	388593	409479	388302	459656	386443	Total
	2365	10372	2342	29936	2080	Fixed
27	189313	191268	188946	197505	189237	Variable
5	88400	88400	88400	88400	88400	Personnel
32	132350	143700	132736	169102	132180	Procurement
	412428	433740	412124	484943	411897	Total
	2376	10383	2353	29947	2091	Fixed
28	196324	198352	195944	204820	196246	Variable
6	90655	90655	90655	90655	90655	Personnel
34	161465	173525	161557	200514	161285	Procurement
	450820	472915	450509	525936	450277	Total
	2386	10393	2363	29957	2101	Fixed
29	203336	205436	202942	212135	203255	Variable
6	92910	92910	92910	92910	92910	Personnel
35	176023	188438	176118	216221	175838	Procurement
	474655	497177	474333	551223	474104	Total
	2397	10404	2374	29968	2112	Fixed
30	210348	212520	209940	219450	210264	Variable
6	95165	95165	95165	95165	95165	Personnel
36	190581	203350	190678	231927	190390	Procurement
	498491	521439	498157	576510	497931	Total
	2407	10414	2384	29978	2122	Fixed
31	217359	219604	216938	226765	217272	Variable
6	97420	97420	97420	97420	97420	Personnel
37	205139	218263	205239	247633	204943	Procurement
	522325	545701	521981	601796	521757	Total

	2418	10425	2395	29989	2133	Fixed
32	224371	226688	223936	234080	224281	Variable
6	99675	99675	99675	99675	99675	Personnel
38	219696	233175	219799	263339	219495	Procurement
	546160	569963	545505	627083	545584	Total
	2429	10436	2406	30000	2144	Fixed
33	231382	233772	230934	241395	231290	Variable
7	101930	101930	101930	101930	101930	Personnnel
40	248812	263000	248920	294752	248600	Procurement
	584553	609138	584190	668077	583964	Total
	2440	10447	2417	30011	2155	Fixed
34	238394	240856	237932	248710	238299	Variable
7	104185	104185	104185	104185	104185	Personnel
41	263370	277913	263481	310458	263153	Procurement
	608389	633401	608015	693364	607792	Total
	2451	10458	2428	3002	2166	Fixed
35	245406	247940	244930	256025	245308	Variable
7	106440	106440	106440	106440	106440	Personnel
42	277928	292825	278041	326165	277705	Procurement
	632225	657663	631839	718652	631619	Total
	2462	10469	2439	30033	2177	Fixed
36	252418	255024	251928	263340	252317	Variable
7	108695	108695	108695	108695	108695	Personnel
43	292485	307738	292602	341871	292258	Procurement
	656060	681926	655664	743939	655447	Total
	2473	10480	2450	30044	2188	Fixed
37	259429	262108	258926	270655	259326	Variable
7	110950	110950	110950	110950	110950	Personnel
44	307043	322650	307162	357577	306810	Procurement
	679895	706188	679488	769226	679274	Total
	2485	10492	2462	30056	2200	Fixed
38	266441	269192	265924	277970	266334	Variable
8	113205	113205	113205	113205	113205	Personnel
46	336159	352475	336283	388990	335915	Procurement
	718290	745364	717874	810221	717654	Total
	2496	10503	2473	30067	2211	Fixed
39	273452	276276	272922	285285	273343	Variable
8	115460	115460	115460	115460	115460	Personnel
47	350717	367388	350844	404696	350468	Procurement
	742125	769627	741699	835508	741482	Total

	2508	10515	2485	30079	2223	Fixed
40	280436	280260	279906	292269	280327	Variable
8	117715	117715	117715	117715	117715	Personnel
48	356274	382300	365404	420402	365020	Procurement
	765933	790790	765510	860465	765285	Total

LIST OF REFERENCES

1. Naval Air Development Center Report NADC-AE-6910, Radar Cross Sections of a Small Boat, by F. C. Prout, 22 December 1969.

2. Department of Transportation, Coast Guard Roles and Missions Study, March 1982.

3. U. S. Coast Guard, Aviation Requirements FY86-90. September 1983.

4. U. S. Coast Guard, Search and Rescue Operating Program Plan FY 87-91, 5 July 1984.

5. U. S. Coast Guard, Enforcement of Laws and Treaties Operating Program Plan FY87-91, 10 August 1984.

6. Operations Evaluation Group, Office of the Chief of Naval Operations Report OEG-56, Search and Screening, by B. O. Koopman, pp. 1-34, 1946.

7. Bloomfield, H. V. L., The Compact History of the United States Coast Guard, Hawthorne Books, p. 17, 1966.

8. Bloomfield, H. V. L., The Compact History of the United States Coast Guard, Hawthorne Books, p. 147, 1966.

9. U. S. Coast Guard, Aviation Requirements FY86-90, p. 1-13, September 1983.

10. U. S. Coast Guard, Aviation Requirements FY86-90, p. 1-7, September 1983.

11. U. S. Coast Guard, Aviation Requirements FY86-90, p. 1-7, September 1983.

12. U. S. Coast Guard, Enforcement of Laws and Treaties Operating Program Plan FY87-91, pp. A-I-22 to A-I-23, 10 August 1984.

13. Naval Postgraduate School Report NPS55f075041 (Revised), Some Notes on Search, Detection and Localization Modeling, by R. N. Forrest, pp. 1-3, November 1983.

14. Operations Evaluation Group, Office of the Chief of Naval Operations Report OEG-56, Search and Screening, by B. O. Koopman, pp. 22-24, 1946.

15. Operations Analysis Study Group, U. S. Naval Academy, Naval Operations Analysis, pp. 85-93, Naval Institute Press, 1977.

16. Naval Air Development Center Report NADC-AE-7022, Flight Test of the AN/APS-116 (XJ-2) Radar, by E. A. Mebus, 14 July 1970.

17. U. S. Coast Guard, CG308, National Search and Rescue Manual, p. 8-71, 1977.

18. U. S. Coast Guard, CG308, National Search and Rescue Manual, pp. 8-71 to 8-72, 1977.

19. Naval Air Development Center Report NADC-AE-6910, Radar Cross Sections of a Small Boat, by F. C. Prout, 22 December 1969.

20. Dornier Report KWS-F08-070-RA, Kampfwertsteigerung Breguet 1150 Atlantic, L. Chabot, 1981, VS-NFD (For Official Use Only).

21. Coast Guard Chief, Office of Operations Letter MCC Serial 13290/13120 to Coast Guard Chief, Office of Engineering, Subject: AN/APS-134 Radar, 17 July 1984.

22. Naval Air Development Center Report NADC-AE-6910, Radar Cross Sections of a Small Boat, by F. C. Prout, p. 1-1, 22 December 1969.

23. Coast Guard Research and Development Center Report C. G.-D-17-84, Evaluation of U. S. Coast Guard Forward-Looking Airborne Radar, by H. G. Ketchen and J. St. Martin, pp. x-xi, March 1984.

24. Naval Air Development Center Report NADC-AE-7022, Flight Test of the AN/APS-116 (XJ-2) Radar, by E. A. Mebus, 14 July 1970.

25. Naval Weapons Center Report NWC-TP-4553, Airborne ASW Radar Detection: A Consideration of the Operator Factor for the AN/APS-88 Radar Under Low Sea State Conditions, by D. G. Kinney, 1 November 1968.

26. U. S. Coast Guard, Enforcement of Laws and Treaties Operating Program Plan FY87-91, pp. A-II-F-3 to A-II-F-4, 10 August 1984.

BIBLIOGRAPHY

Acker, A. E., How to Speak Radar, Varian and Associate, October 1966 Revised January 1974.

Applied Physics Laboratory, Johns Hopkins University, Publication NWA-83-004, Threat Analysis Course, Produced under Navy Contract N00024-836-5301, pp. 39-49, January 1983.

Barton, D. K., Radar System Analysis, Prentis-Hall, 1964.

Department of Transportation, Coast Guard Roles and Missions Report, March 1982.tudy, March 1982.

Hitch, C. J., Decision-Making for Defense, University of California Press, 1965.

Hitch, C. J. and McKean, R. N., The Economics of Defense in the Nuclear Age, Harvard University Press, 1963.

Joiner, B. L. and Ryan, B. F., Minitab Student Handbook, Duxbury Press, 1976.

Mayer, H. A. and Meyer, D. P., Radar Target Detection, Academic Press, 1973.

Naval Air Development Center Report NADC-77283-20, AN/APS-127 Airborne Radar System Evaluation, by O. Kessler and S. R. Swyers, 30 September 1977.

Rand Report P-4587, A Model for Evaluating VSTOL Versus CTOL Combat Aircraft Systems, by S. Horowitz and R. Shishko, March 1971.

Rao, V. V. L., The Decibel Notation, Chemical Publishing, 1946.

Seiler, K., Introduction to Systems Cost-Effectiveness, Wiley-Interscience, 1969.

Sherar, R. C. and Rosenthal, J., "Don't Fall Into the Radar Hole", U. S. Naval Institute Proceedings, pp. 55-66, December 1973.

Smith, J. M., "AN-APS-134 (V) Maritime Surveillance Radar", IEE Conference Publication Number 216, pp. 36-40, 18 October 1982.

U. S. Coast Guard, Aviation Requirements FY87-91 (Draft Copy), September 1984.

U. S. Coast Guard, Commandant Instruction M16018.1A, Planning and Programming Manual, 2 December 1983.

U. S. Coast Guard, Commandant Instruction 3123.7G, Abstract of Operations; Instructions for, 24 August 1982.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code Ø142 Naval Postgraduate School Monterey, California 93943	2
3.	Commandant (G-PTE-1) U. S. Coast Guard 21ØØ 2nd Street S. W. Washington D. C. 2Ø593	2
4.	LT Robert E. Dunn c/o CDR Bill Jacobs 62Ø9 Sodley Church Court Fairfax Station, Virginia 223Ø9	3
5.	Dr. R. N. Forrest, Code 55Fo Operations Research Department Naval Postgraduate School Monterey, California 39343	1
6.	Dr. P. M. Carrick, Code 54Ca Administrative Sciences Department Naval Postgraduate School Monterey, California 93943	1

210708

Thesis
D789892 Dunn
c.1 An analysis of the economic impact of the AN/APS-134 FLAR retro-fit on Coast Guard HC-130 aircraft.